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IMPROVEMENT IN CIMMYT MAIZE POPULATION CZP-132011 THROUGH RECURRENT SELECTION USING HALF SIB FAMILIES

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ABSTRACT

Recurrent selection is a cyclic selection procedure for improving the mean performance of plant populations. The goal of current research was to determine the response of recurrent selection in CIMMYT maize population CZP-132011 using half sib families and to estimate selection differential, heritability, expected response and percent gain cycle^{-1} for yield attributes. Sixty four half sib recurrent families were evaluated in 8×8 lattice square design with two replication at Cereal Crops Research Institute (CCRI), Pirsabak during 2017. Results showed highly significant differences among the half sib families for all the traits. Selection differential values were positive for yield and yield attributing traits. High heritability values ($h^2 > 0.60$) were recorded for all traits except 1000 grain weight (0.54), which exhibited moderate heritability. Based on broad sense heritability and selection differential, the expected response were positive for ears plant^{-1} (0.15), ear length (1.48 cm), ear diameter (0.30 cm), grain rows ear^{-1} (1.30), grains row^{-1} (2.94), 1000 grain weight (14.19 g) and grain yield (153.04 kg ha^{-1}). After one cycle of recurrent selection using half sib families, the positive gain cycle^{-1} values were recorded for all the traits. Viz. Ears plant^{-1} (3.26%), ear length (3.06%), ear diameter (4.99%), grain rows ear^{-1} (2.57%), grains row^{-1} (7.84%), 1000 grain weight (5.87%) and grain yield (4.17%). Based on the findings of current experiment, it could be concluded that bringing improvement in half sib families through recurrent selection method was found effective and population CZP-13200 has the potential of improvement through further recurrent selection.

Key words: Half sib families, recurrent selection, heritability, expected response, gain cycle^{-1}, yield attributes.

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 Khan (2017). 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. 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 *et al*., 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 (Singh *et al*., 2017). Maize is of high importance in a country like Pakistan where the rapidly growing population demands continued food supply (Khalil *et al.,* 2010). In Pakistan maize occupies about 4.8% of total cropped area. Worldwide maize is cultivated over the area of 176.10 million hectares with production of 875.12 million tones and with average yield of 4.944 tones per hectares. (FAO, 2015). In Pakistan area under maize cultivation was 1.20 million hectares with production of 3.7 million tones and with yield of 3.0 tons per hectare, while in KP the area under maize cultivation was 0.6 million hectares with a production of 0.10 million tones and with yield of 0.16 tons per hectare (MINFAL, 2015).

Maize have the highest yield potential, however, in spite 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 high price of hybrid seed. Biotic agents (maize stem borer, leaf blight and stalk rot disease) and abiotic factors (drought/moisture stress) also play role in limiting its potential yield (Galvao *et al.,* 2015). Maize international stock is dwindling and increases the demand of superior cultivars. Population improvement is one of 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 ullah *et al*., 2013). Through half sib families the per se performance of population can be improved. (Wright, 1998). 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., 2016). Knowledge regarding heredity of key traits is necessary for development of superior genotypes. The assessment of genetic component is essential for bringing genetic improvement in populations. Genetic improvement is based on presence of genetic variability in a specie. Enough genetic diversity provide opportunities for selection of promising genotypes and for hybridization. (Goulas *et al.* 2015) The selection differential is the difference between 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 *et al.*, 2015). 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 half sib families of CIMMYT maize population CZP-132011 and to estimate selection differential, heritability, expected response as well as gain cycle^{-1} among the half sib recurrent families for yield attributes.

MATERIALS AND METHODS

The experiment with title "evaluation of half sib recurrent families for expected response and percent gain per cycle" was conducted at Cereal Crop Research Institute (CCRI) Pirsabak, Nowshera during 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 first season (spring) selected half sibs were planted in ear to row. Selection in these families were 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 families data were noted on ears plant^{-1}, ear length, ear diameter, grain rows ear^{-1}, grains row^{-1}, 1000 grain weight 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 Milles et al., (1980) using Mstat-C (1991) statistical package. Means of C_0, C_1, and selected HSF, selection differential, expected response and percent gain cycle^{-1} were estimated for fir yield attributes.

ANOVA format

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 (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 calculated according to Fehr (1987).

$$\text{Gain cycle}^{-1}\ (\%) = \frac{(\text{Cycle}_1 - \text{Cycle}_0)}{\text{Cycle}_0} \times 100$$

RESULTS

Ears plant^{-1}

Mean square revealed significant difference (P≤0.01) among half sib families for ears plant^{-1} in C_1 (Table-1). Population mean of C_0 and C_1 for ears plant^{-1} was 1.10 and 1.14, respectively, while the mean of selected half sib families of C_1 was 1.36. Selection differential for ears plant^{-1} was 0.22. Based on the heritability (0.73) of trait the expected response was 0.16. The gain cycle^{-1} was 3.26% for ears plant^{-1} (Table-2).

Ear length (cm)

Mean square revealed significant difference (P≤0.01) among half sib families for ears length in C_1 (Table-1). Population mean of C_0 and C_1 for ears plant^{-1} was 15.00 cm and 15.46 cm, respectively, while the mean of selected half sib families of C_1 was 17.50. Selection differential for ears length was 2.04 cm. High heritability was recorded for ear length (0.74). Based on the heritability and selection differential of trait the expected response was 1.51 cm and the gain cycle^{-1} for the said trait was 3.26% (Table-2).

Ear diameter (cm)

Mean square revealed significant difference (P≤0.01) among half sib families for ears diameter in C_1 (Table 1). Population mean of C_0 and C_1 for ears plant^{-1} was 2.10 cm and 2.20 cm, respectively, while the mean of selected half sib families of C_1 was 2.25 cm. Selection differential for ears length was 0.38 cm. high heritability

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value was recorded for ear diameter (0.76). Based on the heritability and selection differential of trait the expected response was 0.29 cm. The gain cycle^{-1} was 4.99% ear diameter (Table-2).

Grain rows cob^{-1}

Mean square revealed significant difference (P≤0.01) among half sib families for grain rows cob^{-1} in C_1 (Table-1). Population mean of C_0 and C_1 for grain rows cob^{-1} was 13.75 and 14.10, respectively, while the mean of selected half sib families of C_1 was 15.80. Selection differential for grain rows cob^{-1} was 1.70. Based on the heritability (0.79) of trait the expected response was 1.34. The gain cycle^{-1} was 2.57% for the said trait (Table-2).

Grains row^{-1}

Mean square revealed significant difference (P≤0.01) among half sib families for grains row^{-1} in C_1 (Table-1). Population mean of C_0 and C_1 for grains row^{-1}was 15.25 and 16.45, respectively, while the mean of selected half sib families of C_1 was 20.20 grains row^{-1}. Selection differential for grains row^{-1} was 3.75. High heritability was noted for grains row^{-1} (0.78). Based on the heritability and selection differential of the trait the expected response was 2.94. The gain cycle^{-1} was 7.84% grains row^{-1} (Table=2).

1000 grain weight (g)

Mean square revealed significant difference (P≤0.01) among half sib families for 1000 grain weight in C_1 (Table-1). Population mean of C_0 and C_1 for 1000 grain weight was 246.00 g and 260.45 g, respectively. While the mean of selected half sib families of C_1 was 287.15 g. Selection differential for 1000 grain weight was 26.70 g. Moderate heritability was observed for 1000 grain weight (0.54). Based on the heritability and selection differential of trait the expected response was 14.45 g. The gain cycle^{-1} for 1000 grain weight was 5.87% (Table-2).

Grain yield (kg ha^{-1})

Mean square revealed significant difference (P≤0.01) among half sib families for grain yield in C_1 (Table-1). Population mean of C_0 and C_1 were 3182.50 kg ha^{-1} and 3315.14 kg ha^{-1}, respectively for grain yield. 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 kg ha^{-1}. 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 kg ha^{-1} and the gain cycle^{-1} was 4.17% for grain yield (Table-2).

DISCUSSIONS

Ears plant^{-1}

Ears plant^{-1} along ear length, ear diameter and 1000 grain weight contributes to grain yield. Data concerning ears plant^{-1} expressed highly significant differences among the half sib families of CIMMYT maize population CZP-132011 for ears plant^{-1} in C_1. The current results are in line with Noor et al. (2010) who also observed significant differences among the half sib families of CIMMYT maize varity Pahari for plant and ear height. After one cycle of recurrent selection the percent gain cycle^{-1} for ears plant^{-1} was 3.26%. Positive value of percent gain cycle^{-1} indicates improvement in ears plant^{-1} which is the main aim of plant breeder. Positive value of selection differential and expected response of ears plant^{-1} revealed that further improvement of ears plant^{-1} in possible in maize population CZP132011 through recurrent selection. Pereira et al. (2008) observed positive values of percent gain cycle^{-1}, selection differential and expected response for ears plant^{-1} in five populations of white grain "BRS-ÂNGELA". Maximum heritability value was observed in cycle one for ears plant^{-1}. Hussain et al. (2014) also observed high heritability for ears plant^{-1}.

Ear length and ear diameter

Like other yield components ear length and ear diameter also contribute to final grain yield. Mean squares revealed highly significant differences among half sib recurrent families for ear length and ear diameter. Flachenecker et al. (2006) reported significant differences in modified full sib families for ear length and ear diameter, while Santos *et al.* (2005) noted significant difference in IG-1 and IG-2 maize populations for ear length and ear diameter. After one cycle of recurrent selection, the gain cycle^{-1} of ear length and ear diameter were 3.06 and 4.99% respectively. Noor *et al.* (2013) got 11.25% gain cycle^{-1} for ear length. Positive value of percent gain cycle^{-1} indicates improvement in ear length and ear diameter. (Khalil *et al*., 2010) reported high heritability and positive selection differential for ear length and ear diameter. Mahmood *et al.* (2004) and Bekele *et al*. 2014 also got high heritability for ear length and ear diameter. Based on selection differential and heritability we got high expected response for ear length and ear diameter.

Grains row ear^{-1} and grains row^{-1}

Grains row ear^{-1}, grains row^{-1}, ear length, ear diameter and 1000 grain weight adds to ultimate grain weight. Statistical results showed highly significant differences among half sib families for grains row ear^{-1} and grains row^{-1}. Our results for the mentioned are in line with Dona *et al.* (2012), who also noted significant differences in two recombination cycles. After one cycle of recurrent selection in half sib families of CIMMYT maize population CZP-132011, the percent gain cycle^{-1} for grains row ear^{-1} and grains row^{-1} were 2.57 and 7.84% respectively. In full sib families of maize Berilli *et al.* (2013) also noted improvement for grains row ear^{-1} and grains row^{-1} using 11 cycle of reciprocal recurrent selection. The selection differential for grains row ear^{-1} and grains row^{-1} were 1.70 and 3.75 respectively. High heritability values for grains row ear^{-1} (0.79) and grains row^{-1} (0.78) indicates that these traits were comparatively under less environmental influence. Based on high heritability and selection differential, the expected response for the mentioned traits were 1.34 and 2.94.

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1000 grain weight

Grain weight contribute directly to final grain yield. Grain with large grain size have high grain yield. Data regarding 1000 grain weight exhibited significant differences among the recurrent half sib families for 1000 grain weight. (Ahmad *et al*., 2012) also reported significant differences among the half sib families of maize variety Sarhad white for 1000 grain weight. After one cycle of recurrent selection, the percent gain cycle^{-1} was 5.87%. Improvement in percent gain cycle^{-1} for 1000 grain weight was also reported by Oliveira et al. (2015) and Lujiang et al. (2015). Positive value of percent gain cycle^{-1} reflects the increase in 1000 grain weight which is desirable for plant breeders. Positive values of selection differential and expected response reflects that further improvement is possible in 1000 grain weight using recurrent half sib families. Moderate heritability shows that there is environmental influence on 1000 grain weight, whereas high index of variation reflects the presence of greater genetic variability.

Grain yield

Yield is a complex trait, which is the interaction of several yield attributing traits. Mean squares revealed highly significant differences among 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 significant difference in UENF-14 popcorn population using recurrent selection procedure for grain yield. Similarly Weyhrich *et al.* (2012) also noted significant differences in BS-11 maize population. 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. Positive value of percent gain cycle^{-1} reflects improvement in grain yield using recurrent selection procedure. Ishaq *et al*. (2014) noted 1233.42 kg ha^{-1} selection differential and 900.99 kg ha^{-1} expected response for grain yield in half sib families of maize population Sarhad White. Positive value of selection differetional 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.

CONCLUSIONS AND RECOMENDATIONS

Analysis of variance revealed highly significant differences for all the studied traits, indicate the existence of sufficient amount of genetic variability among the half sib families for further improvement and potential for recurrent selection. Here we noted for first time that CIMMYT maize population CZP-132011 have sufficient genetic variability and a remarkable improvement through recurrent selection. Based on the findings of current experiment, it could be concluded that bringing improvement in half sib families through recurrent selection method was found effective and population CZP-13200 has the potential of improvement through further recurrent selection.

Table-1. Mean squares and coefficient of variation of half sib recurrent families of cycle one for yield and yield attributing traits.

Trait	Mean	squares	
	Families (df=64)	Error (df=49)	Coefficient of variation (%)
Ear plant^{-1}	0.05**	0.01	7.53
Ear length	2.94**	0.44	4.29
Ear diameter	0.16**	0.02	6.72
Grain rows ear^{-1}	2.17**	0.26	3.60
Grains row^{-1}	13.78**	1.67	7.87
1000 grain weight	840.24**	250.13	6.08
Grain yield	100630.25**	21196.52	4.39

** = significant at 1% level of probability.

Table-2. Population mean (μ) of C_o and C_1, mean of selected half sib families (μHS), heritability (h^2), selection differential (S), expected response (Re) and percent gain per cycle for yield attributes of C_1.

Parameter	C_o	C_1		h^2	S	Re	% gain cycle^{-1}
	μ	μ	μHS				
Ears plant^{-1}	1.10	1.14	1.36	0.73	0.22	0.16	3.26
Ear length	15.00	15.46	17.50	0.74	2.04	1.51	3.06
Ear diameter	2.10	2.20	2.58	0.76	0.38	0.29	4.99
Kernel rows ear^{-1}	13.75	14.10	15.80	0.79	1.70	1.34	2.57
Grains row^{-1}	15.25	16.45	20.20	0.78	3.75	2.94	7.84
1000 grain weight	246.00	260.45	287.15	0.54	26.70	14.45	5.87
Grain yield	3182.50	3315.14	3553.50	0.65	238.36	155.41	4.17

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