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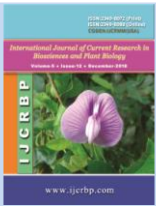

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Evidence of Improving Yield and Yield Attributes *Via* Half-sib Family Recurrent Selection in Maize (*Zea mays* L.)

Amir Sohail[1]*, Quaid Hussain[1], Shahzad Ali[2], Manzoor[2], FazalHadi[3], Salah Uddin[3], Faisal Bashir[1], Muhammad Asad[3], Sidra Sami[3] andZarghuna Yousafzai[3]

[1]Department of Plant Breeding and Genetics, The University of Agriculture, Peshawar, KPK, Pakistan
[2]Department of Agronomy, The University of Agriculture, Peshawar, KPK, Pakistan
[3]Department of Botany, University of Peshawar, KPK, Pakistan

***Corresponding author.**

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ABSTRACT

Recurrent selection is a cyclical selection procedure for improving the mean performance of plant populations. The goal of current research was to determine genetic variability, heritability, selection differential, expected response, percent gain cycle^{-1} and genotypic and phenotypic correlations among various traits. Sixty four half sib recurrently selected families derived from CIMMYT maize population CZP-132011 were evaluated in 8×8 square lattice design with two replications at Cereal Crops Research Institute (CCRI), Pirsabak during 2017. Data were noted on ear plant^{-1}, ear length, ear diameter, grain rows ear^{-1}, grains row^{-1}, 1000 grain weight and grain yield. Results showed highly significant differences among half sib families for all the studied traits. High heritability ($h^2 > 0.60$) was recorded for all traits except 1000 grain weight which exhibited moderate heritability. High index of variation (I.V > 1.00) was observed for all traits. Based on heritability and selection differential, the expected response was negative for plant height (-2.81 cm) and ear height (-5.22 cm), while positive expected response was recorded 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 in these half sib families, the gain cycle^{-1} was recorded negative for plant height (-2.34%), ear and height (-4.90%),while positive gain cycle^{-1} was observed for 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%).Grain yield exhibited significant and positive correlation with ear length ($r_G = 0.50^{**}$ and $r_P = 0.33^{*}$) both at genotypic and phenotypic levels. Based on the findings of current experiment, it could be concluded that improvement in half sib families through recurrent selection method was found effective and population CZP-132011 has the potential of improvement through further recurrent selection.

Introduction

Maize (*Zea mays* L.) is an annual, short day crop with monecious flower and originated in Mexico (Sohail et al., 2018). 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. 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 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. Maize is of high importance in a country like Pakistan where the rapidly growing population demands continues food supply. In Pakistan maize occupies about 4.8% of total cropped area. Worldwide maize is cultivated over an area of 176.10 million hectares with production of 875.12 million tons and average yield of 4.944 tons per hectares (FAO, 2015). In Pakistan area under maize cultivation was 1.20 million hectares with production of 3.7 million tones and average 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 average yield of 0.16 tons per hectare (MINFAL, 2015).

Maize has 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. Maize international stock is dwindling and increase in the population demands of superior cultivars. Population improvement is one of the essential aspects in maize breeding. 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 sibs refer to individuals having one parent in common. Half sib family selection is a type of recurrent selection used for intrapopulation improvement that comprises the evaluation of half sib families through half sib progeny (KaleemUllah et al., 2013). Through half sib families the per se performance of population can be improved (Wright, 1998). Maize breeders often use recurrent selection method based on half sib families. Recurrent selection increases the frequencies of desirable alleles and fixes it rapidly hence maintains genetic variability, while the homozygous deleterious alleles are exposed to selection and eliminated early from the population. A cycle of recurrent selection constitutes three phases: i) development of half sib families, ii) evaluation of families and iii) recombination of selected families. Recurrent selection method is frequently used for quantative traits improvement (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 breeding populations. Genetic improvement is based on presence of genetic variability in a species. Enough genetic diversity provides opportunities for selection of promising genotypes and probably for hybridization. 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., 2014). Half sib families have been utilized and proved effective for maize populations improvement. Keeping in view the above importance of recurrent selection using half sib families, this experiment was conducted with the following objectives to: 1) evaluate the effect of recurrent selection in CIMMYT maize population (CZP-132011) for flowering, morphological and yield attributes. 2) estimate the selection differential and expected response after one selection cycle. 3) estimate the variance components, heritability and index of variation after one selection cycle. 4) know the efficiency of half sib recurrent families by estimating percent gain cycle^{-1}. 5) study genotypic and phenotypic correlations of maturity and yield attributes.

Materials and methods

To study "Improvement in maize population CZP-13201 through recurrent selection using half sib families" this experiment was conducted at the Cereal Crops Research Institute (CCRI) Pirsabak, Nowshera during 2017. Breeding material were 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 spring season (March-June, 2017) selected half sib families (80) were constituted from an early experimental CIMMYT maize population (CZP-132011). These half sib families (HSF) were planted in ear to row. Selection in these families was done at the flowering stage on the basis of plant vigor, uniformity, earliness, diseases and insect resistance. The selected families (Rows) were intermated through controlled hand pollination using bulk pollination method. At maturity all the hand pollinated ears from each selected family were harvested. Selection of best families based on uniformity, disease freeness and with heavy seed sitting was done. During second season of summer (July-October) a set of those selected families along with base population were planted in 8×8 square lattice design with two replications. Row length was 5m, row to row distance was 75cm and plant to plant distance was 25 cm. The selected families were evaluated for flowering, morphological and yield attributing traits. Based on visual observation at least 15% selection was followed at harvest as to start new version of recurrent selection cycle for further study in future aimed at genetic improvement of the said population.

Data were taken on ears plant^{-1}, ear length (cm), ear diameter, kernel rows ear^{-1}, kernels row^{-1}, 1000 kernel weight, gain yield (kg ha^{-1}). Grain yield was calculated after physiological maturity by collecting ears from each entry using the following formula.

$$\text{Grain Yield (kg ha}^{-1}\text{)} = \frac{\text{Fresh ear weight (kg plot}^{-1}\text{)} \times (100\text{-MC}) \times 0.8 \times 10000}{(100\text{-}15) \times (\text{plot}^{-1}\text{ area})}$$

Where,

MC = grain moisture content (%) in grains at harvest.
0.8 = shelling coefficient.
Plot^{-1} area = 3.75 m^2.
1 hectare = 10,000 m^2.
15% = grain moisture content required at storage.

Statistical analysis

Data recorded on each trait was subjected to analysis of variance (ANOVA) appropriate for square lattice design as suggested by Milles et al., (1980) using Mstat-C (1991) statistical package.

Table A: Analysis of variance 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	$\sigma^2 E$

Variance components of heritability were calculated as under:

M_1 (Error mean squares) = $\sigma^2 E$
M_2 (HS mean squares) = $\sigma^2 E + r\sigma^2 G$
Genotypic variance ($\sigma^2 G$) = $M_2 - M_1/r$
Phenotypic variance ($\sigma^2 P$) = $\sigma^2 E + r\sigma^2 G / r$

1) Heritability (b.s) for each traits were calculated according to Allard (1960) as:

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

2) 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

3) Expected response (Re) was work out as:

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

4) Percent gain cycle^{-1} was calculated according to Fehr (1987).

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

5) Genotypic and environmental coefficient of variation were calculated according to Johnson et al. (1955):

$$GCV = \sigma G/y \times 100$$
$$ECV = \sigma E/y \times 100$$

6) Index of variation (I.V), measure the relative variability as:

$$I.V = GCV/ ECV$$

7) Genotypic and phenotypic correlation coefficients were computed according to Singh and Chaudhary (1979) using META-R statistical package.

$$\text{Genotypic correlation coefficient (rgxy)} = \sigma Gxy / \sqrt{\ } \sigma^2 Gx.\ \sigma^2 Gy$$

$$\text{Phenotypic correlation coefficient (rpxy)} = \sigma Pxy / \sqrt{\ } \sigma^2 Px.\ \sigma^2 P$$

Results

Ears plant^{-1}

Mean square showed significant ($P \leq 0.01$) differences among the 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 (0.66) of trait, the expected response was 0.15. The gain cycle^{-1} was 3.26% for the mentioned trait (Table 2). For ears plant^{-1}, the genetic, environmental and phenotypic variances was 0.02, 0.01 and 0.03, respectively (Table 3). Genotypic and environmental coefficient of variation for ears plant^{-1} was 12.17% and 8.74%, respectively with an index of variation of 1.39 (Table 4). Ears plant^{-1} exhibited highly significant and positive genotypic correlation with grain rows ear^{-1} (r_G= 0.38**) and grain yield (r_G= 0.46**), while ears plant^{-1} showed non-significant correlation with remaining traits (Table 5).

Table 1. Mean squares and coefficient of variations for flowering and yield attributing traits in half sib families of CIMMYT maize population CZP-132011.

Trait	Mean squares		Coefficient of variation
	Families	Error	(%)
Plant height	23.43**	6.74	1.61
Ear height	39.43**	7.63	3.84
Ear plant^{-1}	0.04**	0.01	8.64
Ear length	2.97**	0.47	4.43
Ear diameter	0.27**	0.03	8.55
Grain rows ear^{-1}	2.16**	0.29	3.81
Grains row^{-1}	13.83**	1.67	7.87
1000 grain weight	840.24**	256.99	6.16
Grain yield	100630.25**	21935.53	4.47

** = Significant at 1% level of probability.

Ear length

Mean square revealed significant ($P \leq 0.01$) difference among the half sib families for ear length in C_1 (Table 1). Population mean of C_0 and C_1 for ear length was 15.00 cm and 15.46 cm, respectively, while the mean of selected half sib families of C_1 was 17.50 cm. Selection differential for ear length was 2.04 cm. Based on the heritability (0.73) of trait, the expected response was 1.48 cm. The % gain cycle^{-1} was 3.26% (Table 2). For ear length, the genetic, environmental and phenotypic variances were 1.25, 0.47 and 1.72, respectively (Table 3). Genotypic and environmental coefficient of variation for ear length was 7.24% and 4.42%, respectively with an index of variation of 1.63 (Table 4). Ear length exhibited significantly and positive genotypic correlation with 1000 grain weight (r_G= 0.28*) and grain yield (r_G= 0.50**). However, ear length showed significant and negative correlation with grain rows ear $^{-1}$ (r_G= -0.23*), while with remaining traits it showed non-significant correlation (Table 5).

Table 2. Population mean (μ) of C_o and C_1, mean of selected half sib families (μHS), selection differential (S), Expected response (Re) and percent gain per cycle for flowering and yield attributing traits.

Parameter	C_o	C_1		S	Re	Gain cycle^{-1} (%)
	μ	μ	μHS			
Plant height	165.00	161.13	156.06	-5.07	-2.81	-2.34
Ear height	75.50	71.80	64.07	-7.73	-5.22	-4.90
Ears plant^{-1}	1.10	1.14	1.36	0.22	0.15	3.26
Ear length	15.00	15.46	17.50	2.04	1.48	3.06
Ear diameter	2.10	2.20	2.58	0.38	0.30	4.99
Kernel rows ear^{-1}	13.75	14.10	15.80	1.70	1.30	2.57
Grains row^{-1}	15.25	16.45	20.20	3.75	2.94	7.84
1000 grain weight	246.00	260.45	287.15	26.70	14.19	5.87
Grain yield	3182.50	3315.14	3553.50	238.36	153.04	4.17

Table 3. Genetic variance (σ^2_G), environmental variance (σ^2_E), phenotypic variance (σ^2_P) and broad sense heritability (h^2 (b.s)) for flowering and yield attributing traits in half sib families.

Trait	σ^2_G	σ^2_E	σ^2_P	h^2 (b.s)
Plant height	8.35	6.74	15.08	0.55
Ear height	15.90	7.63	23.53	0.68
Ears plant^{-1}	0.02	0.01	0.03	0.66
Ear length	1.25	0.47	1.72	0.73
Ear diameter	0.12	0.03	0.15	0.79
Grain rows ear^{-1}	0.94	0.29	1.23	0.76
Grains row^{-1}	6.08	1.67	7.75	0.78
100 grain weight	291.62	256.99	548.61	0.53
Grain yield	39347.36	21935.53	61282.89	0.64

Ear diameter

Mean square revealed significant ($P \leq 0.01$) differences among the half sib families for ear diameter in C_1 (Table 1). Population mean of C_0 and C_1 for ear diameter 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 ear diameter was 0.38 cm. Based on the heritability (0.79) of trait, the expected response was 0.30 cm. The gain cycle^{-1} was 4.99% for the said trait (Table 2). For ear diameter, the genetic, environmental and phenotypic variances were 0.12, 0.03 and 0.15, respectively (Table 3). Genotypic and environmental coefficient of variation for ear diameter was 16.52% and 8.51%, respectively with an index of variation of 1.94 (Table 4). Ear diameter revealed non-significant correlation with all the studied traits both at genotypic and phenotypic levels (Table 5).

Grain rows ear^{-1}

Mean square exhibited significant ($P \leq 0.01$) difference among the half sib families for kernel rows ear^{-1} in C_1 (Table 1). Population mean of C_0 and C_1 for kernel rows ear^{-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 kernel rows ear^{-1} was 1.70. Based on the heritability (0.76) of trait, the expected response was 1.30. The gain cycle^{-1} for the mentioned trait was 2.57% (Table 2). For kernel rows ear^{-1}, the genetic, environmental and phenotypic variances were 0.94, 0.29 and 1.23, respectively (Table 3). Genotypic and environmental coefficient of variation for kernel rows ear^{-1} was 6.86% and 3.81%, respectively with an index of variation of 1.80 (Table 4). Grain rows ear^{-1} exhibited significant and positive genotypic correlation with ears plant^{-1} (r_G= 0.38**), 1000 grain weight (r_G= 0.23*) and grain yield (r_G= 0.24*), while significant and negative phenotypic correlation was observed with ear length (r_P= -0.23*). Grain rows ear^{-1} showed non-significant association with the remaining traits at both levels (genotypic and phenotypic) (Table 5).

Table 4. Genetic coefficient of variation (GCV), environmental coefficient of variation (ECV) and index of variation (I.V) for flowering and yield attributing traits in half sib families.

Parameter	GCV (%)	ECV (%)	I.V
Plant height	1.79	1.61	1.11
Ear height	5.55	3.84	1.44
Ears plant^{-1}	12.17	8.74	1.39
Ear length	7.24	4.43	1.63
Ear diameter	16.52	8.51	1.94
Grain rows ear^{-1}	6.86	3.81	1.80
Grains row^{-1}	15.00	7.87	1.91
1000 grain weight	6.56	6.16	1.07
Grain yield	5.99	4.47	1.34

Table 5. Coefficient of genetic correlation (below the diagonal) and phenotypic correlation (above the diagonal) among the various traits of half sib recurrent families.

Traits	PH	EH	EPP	EL	ED	GRE	GPR	1000 GW	GY
PH	1	0.14	-0.04	-0.10	0.02	0.07	0.02	-0.06	0.01
EH	0.34**	1	-0.14	0.07	-0.11	0.07	-0.11	0.10	0.14
EPP	0.00	-0.12	1	0.10	-0.03	0.02	0.14	-0.01	0.20
EL	-0.05	0.02	0.21	1	0.17	-0.23*	0.06	0.16	0.33**
ED	0.11	-0.09	0.21	0.22	1	-0.08	-0.08	-0.09	-0.02
GRE	0.13	0.05	0.38**	-0.14	0.06	1	0.01	0.16	0.10
GPR	0.06	-0.18	0.11	0.03	0.01	0.09	1	-0.29*	0.15
100GW	0.00	0.03	0.16	0.28*	-0.02	0.23*	-0.28*	1	0.20
GY	-0.04	0.19	0.46**	0.50**	-0.02	0.24*	0.34**	0.39**	1

*, ** = significant at 1 and 5% probability level; DT = days to tasseling, DA = days to anthesis, DS = days to silking, ASI = anthesis silking interval, PH = plant height, EH = ear height, EPP = ears plant^{-1}, EL = ear length, ED = ear diameter, GRE = grain rows ear^{-1}, GPR = grains row^{-1}, 1000 GW = 1000 grain weight and GY = grain yield.

Grains row^{-1}

Mean square revealed significant ($P \leq 0.01$) differences among the 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. Selection differential for grains row^{-1} was 3.75. Based on the heritability (0.78) of trait the expected response was 2.94. The gain cycle^{-1} for the mentioned trait was 7.84% (Table 2). For grains row^{-1}, the genetic, environmental and phenotypic variances were 6.08, 1.67 and 7.75, respectively (Table 3). Genotypic and environmental coefficient of variation for grains row^{-1} was 15% and 7.87%, respectively with an index of variation of 1.91 (Table 4). Grains row^{-1} exhibited significant and negative genotypic correlation with 1000 grain weight (r_G= -0.28*). Significant and positive correlation was noted with grain yield at genotypic level (r_G= 0.34**). However, grains row^{-1} had non-significant correlation with remaining studied traits at both levels (Table 5).

1000 grain weight

Mean square revealed significant ($P\leq0.01$) differences among the 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 260.45g, 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 value (0.53) was noted for 1000 grain weight. Based on selection differential and heritability of trait, the expected response was 14.19 g. The gain cycle^{-1} was 5.87% for the mentioned trait (Table 2). For 1000 grain weight, the genetic, environmental and phenotypic variances were 291.62, 256.99 and 548.61, respectively (Table 3). Genotypic and environmental coefficient of variation for 1000 grain weight was 6.56% and 6.16%, respectively with an index of variation of 1.07 (Table 4). Thousand grain weight exhibited significant and positive genotypic correlation with ear length (r_G= 0.28*), grain rows ear^{-1} (r_G= 0.23*) and grain yield (r_G= 0.39**), while significant and negative genotypic correlation was observed with grains row^{-1} (r_G= -0.28*). The mentioned trait showed significant ant negative phenotypic correlation was grains row^{-1} (r_P= -0.29*). With the remaining traits 1000 grain weight revealed non-significant association at both levels (genotypic and phenotypic) (Table 5).

Grain yield (kg ha^{-1})

Mean square revealed significant ($P\leq0.01$) differences among the half sib families for grain yield in C_1 (Table 1). Population mean 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 kg ha^{-1}. Based on the heritability (0.64) of trait, the expected response was 153.04 kg ha^{-1}. The gain cycle^{-1} was 4.17% for the said trait (Table 2). For grain yield, the genetic, environmental and phenotypic variances were 39347.36, 21935.53 and 61282.89 respectively (Table 3). Genotypic and environmental coefficient of variation for grain yield was 5.99% and 4.47%, respectively with an index of variation of 1.34 (Table 4). Grain yield had significant genotypic correlation with ears plant^{-1} (r_G= -0.46**), ear length (r_G= 0.50**), grain rows ear^{-1} (r_G= -0.24*), grains row^{-1} (r_G= 0.34**) and 1000 grain weight (r_G= 0.39*). Grain yield exhibited significant and positive phenotypic correlation with ear length (r_P= 0.33**). The mentioned trait showed non-significant correlation with the remaining traits at both genotypic and phenotypic levels (Table 5).

Discussion

Plant and ear height

Plant and ear height are important agronomic traits which play an important role in lodging and ultimately affect the final grain yield. Maize breeders should give preference to plant and ear height in order to prevent lodging in maize populations. Mean squares showed significant ($P\leq0.01$) differences among the half sib recurrent families for plant and ear height in C_1. Our results are in line with Khalil et al. (2010) who also noted significant differences among S_1 lines of Azam maize population for plant and ear height. Similarly Andrade et al. (2008) observed significant differences in maize population, ESALQ-PB1 for plant and ear height. However, Asin et al. (2015) reported highly significant differences in full sib families for plant height. 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 decrease in plant and ear height which is highly desirable for maize breeders. Intermediate plant and ear height is desirable for resisting against lodging. Negative values of selection differential and expected response indicate that no further improvement is possible for plant and ear height.

Intermediate heritability vales were noted for plant and ear height. Mahmood et al. (2004) also noted moderate heritability in maize hybrids for plant and ear height. High index of variation was noted for plant and ear height showing high genetic variability and selection possibility. Peterniani et al., (2004) also noted high index of variation for plant and ear height in maize composite. Plant height had negative genotypic association with grain yield at genotypic level. While, positively correlated at phenotypic level. Barua et al. (2017) and Nzuve et al. (2014) noted negative genotypic and phenotypic association of plant height with ear length, while ear height exhibited positive genotypic and phenotypic correlation with grain yield.

Ears plant^{-1}

Ears plant^{-1} along with 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 recurrent families of maize population CZP-132011. The current findings are in line with Noor et al. (2010) who also noted significant ($P \leq 0.01$) differences among half sib recently families of maize Varity Pahari for plant and ear height, while Alves et al. (2015) reported significant differences in fifth recurrent cycle in maize progenies for ears plant^{-1}. After one cycle of recurrent selection the 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 maize breeders. Positive value of selection differential and expected response of ears plant^{-1} revealed that further improvement of ears plant^{-1} is possible in maize population CZP132011 through recurrent selection. Pereira et al. (2008) observed positive values for percent gain cycle^{-1}, selection differential and expected response for ears plant^{-1} in five populations of white grain "BRS-ANGELA”. Maximum heritability value was observed in cycle one for ears plant^{-1}. Hussain et al. (2014) also noted high heritability for ears plant^{-1}. High index of variation for ears plant^{-1} revealed presence of genetic variability and selection possibilities. Correlation analysis showed positive genotypic correlation with all the traits except ear height. Ears plant^{-1} was positively correlated with all traits except plant height, ear height, ear diameter and 1000 grain weight at phenotypic level. Malik et al. (2005) noted positive correlation between ears plant^{-1} and grain yield both at genotypic and phenotypic levels.

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 ($P \leq 0.01$) differences among the 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. Similarly Wardyn et al. (2009) observed in three maize populations for cob length, 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 percent gain cycle^{-1} of ear length and ear diameter was 3.06 and 4.99%, respectively. Noor et al. (2013b) reported 11.25% gain cycle^{-1} for ear length. Positive value of gain cycle^{-1} indicates improvement in ear length and ear diameter. Selection differentials were positive for ear length and ear diameter. High heritability was observed for ear length and ear diameter. Bekele et al. (2014) observed high heritability for ear length and ear diameter in maize hybrids. Similarly Mahmood et al. (2004) also reported high heritability for ear length and ear diameter in semi exotic (*Zea mays* L.) populations. Based on selection differential and heritability we got high expected response for ear length and ear diameter. High index of variation revealed the presence of genetic variability and possibilities of selection. The mentioned traits were positively correlated with 1000 grain weight at both genotypic and phenotypic levels. Ear length had highly significant and positive genotypic and phenotypic relationship with grain yield, while ear diameter showed negative genotypic and phenotypic relationship with grain yield. Barros et al. (2010) also noted negative correlation between ear diameter and grain yield, while Bekele et al.

(2014) noted positive association between grain yield and ear length and ear diameter both at genotypic and phenotypic levels.

Grain rows ear^{-1} and grains row^{-1}

Grain rows 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 the half sib families in cycle one for grain rows ear^{-1} and grains row^{-1}. Our results for the mentioned traits 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 maize population CZP-132011, the gain cycle^{-1} for grain rows 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 grain rows ear^{-1} and grains row^{-1}, using 11 cycles of reciprocal recurrent selection. The selection differential for grain rows ear^{-1} and grains row^{-1} was 1.70 and 3.75, respectively. High heritability values for grain rows ear^{-1} (0.79) and grains row^{-1} (0.78) indicates that these traits were under less environmental influence. Based on high heritability and selection differential the expected response for the mentioned traits was 1.34 and 2.94. High value of I.V > 1 indicates the possibility of selection. Maximum heritability, selection differential, expected response and index of variation were also noted for grain rows ear^{-1} and grains row^{-1} by Rodrigues et al. (2011). Grain rows ear^{-1} and grains row^{-1}were significantly and positively associated with grain yield at only genotypic level. Positive genotypic and phenotypic correlation was noted between grain rows ear^{-1}, grains row^{-1} and grain yield by Bekele et al. (2014).

1000 grain weight

Grain weight contribute directly to final grain yield. Grain with large grain size have high grain yield. Data of 1000 grain weight exhibited significant ($P \leq 0.01$) differences among the recurrent half sib families for 1000 grain weight. Aliu et al. (2012) noted significant differences for grain weight in Kosovo local maize populations. After one cycle of recurrent selection, the gain cycle^{-1} was 5.87%. Improvement in percent gain cycle^{-1} for 1000 grain weight was also noted by 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 reflect that further improvement is possible in1000 grain weight using recurrent half sib families. Moderate heritability and index of variation reflects that there is environmental influence on 1000 grain weight. Mahmood et al. (2004) also noted moderate heritability for grain weight. Low and moderate index of variation reduce the possibilities of genetic variability and chances of selection Pixley et al. (2006). Thousand grain weight was positive correlated at genotypic and phenotypic levels with plant and ear height, ears plant^{-1}, ear length, grain rows ear^{-1} and grain yield, while negatively associated with ear diameter and grains row^{-1}genotypically. However, 1000 grain weight was positively correlated with all traits except ear diameter phenotypically. Bekele et al. (2014) ifound positive correlation between 1000 grain weight and ears plant^{-1}, ear length and grain yield. Malik et al. (2005) also noted positive association of 1000 grain weight with ears plant^{-1}, ear length and grain yield at phenotypic level.

Grain yield

Yield is a complex trait which is the interaction of several yield attributing traits. Mean squares exhibited highly significant differences among the half sib recurrent families for grain yield. After one cycle of recurrent selection the 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. (2013b) 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 selection differential and 900.99expected response for grain yield in the 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 in maize hybrids. High index of variation (1.37) was noted for the said trait reflects the presence of genetic variability and chances of selection. Andrade et al. (2008) also reported I.V > 1 for grain yield in maize population, ESALQ-PB1. Grain yield was negatively associated with plant height and ear diameter at both genotypic and phenotypic levels, while positively correlated with ear height, ears plant^{-1}, ear length, grain rows ear^{-1}, grains row^{-1} and 1000 grain weight at both genotypic and phenotypic levels. Kaleemullah et al. (2013) and Singh et al. (2017) also noted positive genotypic and phenotypic correlation of grain yield with ears plant^{-1}, ear length and 1000 grain weight. Durrishahwar et al. (2008) also reported positive phenotypic association of grain yield with ear length, kernel rows ear^{-1} and kernel weight.

Conclusions and recommendations

Highly significant differences were noted among recurrent half sib families for all the studied traits. Heritability values ranged from 0.53 to 0.79 and was high for all most all traits except plant height and 1000 grain weight. High index of variation (I.V > 1.00) was noted for all traits. Negative selection differential values were recorded for plant and ear height while, Positive selection differential values were recorded for yield and yield attributing traits. Based on selection differential and heritability of traits, the expected response was negative for flowering and morphological traits, while positive for yield and yield attributes. Gain cycle^{-1} was negative for flowering and morphological traits, while positive for yield and yield attributes. Most of the yield attributes were positively correlated with grain yield both at genotypic and phenotypic levels. Based on the findings of current experiment, it could be concluded that improvement in half sib families through recurrent selection was effective and population CZP-132011 has the potential for improvement through further recurrent selection using half sib families.

Conflict of interest statement

Authors declare that they have no conflict of interest.

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