ESTIMATES OF HERITABILITY AND EXPECTED RESPONSE FOR MATURITY AND GRAIN YIELD RELATED TRAITS IN HALF-SIB RECURRENT FAMILIES OF MAIZE

Muhammad Ishaq[1,2*], Ghulam Hassan[1],HidayaturRahman[1],Muhammad Iqbal[2], Ibni Amin Khalil[1], Sabaz Ali Khan[3],SherazAhmad Khan[1],Rafiullah[1], and Jamal Hussain[3]

[1]*Department of Plant Breeding and Genetics, Agricultural University Peshawar, Khyber-Pakhtunkhwa, Pakistan,* [2]*Cereal Crops Research Institute (CCRI) Pirsabak, Nowshera, Pakistan,* [3]*Department of Environmental Sciences, COMSATS Institute of Information Technology, 22060, Abbottabad, Pakistan*   E-mail*: ishaqaup@gmail.com

ABSTRACT

Genetic improvement of the segregating populations is an important aspect of the maize breeding programs. This research was undertaken to estimate heritability and expected responses for maturity and grain yield related traits in maize. For this purpose, one hundred and forty-four half-sib families that were derived from Sarhad white maize population were used. These half-sib families were statistically evaluated in a partially balanced 12x12 lattice design. The heritability estimates varied from 0.28 to 0.88 and were high for days to teaseling, days to silking, days to pollen shedding, ear height, kernels row^{-1}, grain yield, medium plant height, 1000 kernel weight and low for kernels ear^{-1}. The genetic and environmental coefficients of variation varied from 1.85 to 16.13 and 1.64 to 13.85, respectively. The index of variation ranged from 0.44 to 1.92 among the traits. Based on the values of the heritability and selection differential the highest expected response was observed for grain yield (900.99 kg ha^{-1}) followed by 1000 kernel weight (2.51g), plant height (3.26 cm) and ear height(2.72cm). These high heritability and high index of variation estimates (I.V >1) for various important traits indicates greater heterogeneity and genotypic differences among the tested half-sib families. We have shown for the first time that this improved recurrent population Sarhad white has the potential to recurrent selection and could be used in future maize breeding programs. Moreover, the improved recurrent population might be used by poor farmers to save production cost and to use the seeds for future farming.

KEYWORDS: Segregating population, recurrent selection, selection differential, index of variation, half-sib, lattice design, *Zea mays* L.

INTRODUCTION

Maize (*Zea mays* L.), a member of family Poaceace is a typical all zoogamous species with prevalence of cross pollination as source of fertilization. It is extensively grown in temperate, tropical and subtropical regions of the world. Its range of adaptability stretches over 50^0 N to 40^0 S in latitude and up to 3300 meters in altitude of above the sea level (Shah et al., 2006). Maize ranks third among the cereal crops after wheat and rice that accounts for

4.8 % of the total value of agricultural outputs on global level. The leading maize producers are United States of America, China, Brazil, Argentina, and Mexico. World area under cultivation of maize crop is 176991.9 thousand hectares with a total production of 875098.63 thousand tones and an average yield of 4.835t ha^{-1} (FAO, 2013). In Pakistan, maize is grown on an area of 1052 thousand hectares with a total production of 3593 thousand tones and an average yield of 3415 kg ha^{-1}, while in Khyber-Pakhthunkhawa province, area under cultivation is 500 thousand hectares with a production of 900 thousand tones and an average yield of 1.7 t ha^{-1} (MINFAL, 2008). It is used both for food (grains) and fodder purposes.

Population improvement is an essential aspect in maize breeding programs. Several breeding methodologies have been used by the maize breeders for improving the yield and for developing the high yielding maize varieties. These include mass selection, ear to row selection, modified ear to row selection and various other methods of recurrent selection including half-sib and self-generations of base population. Recurrent selection has been proposed as a method of improvement in maize. Hull (1952) defined recurrent selection as "reselection generation after generation, with interbreeding of selects to provide for genetic recombination". The objectives of recurrent selection are to: (1) increase the frequency of favourable alleles at the cost of unfavourable or undesirable alleles in the population while maintaining the genetic variability and (2) to improve the performance of population for one or more traits. Half-sib refers to individuals having only one parent in common. Recurrent half-sib selection is a method of intra-population improvement that involves the evaluation of individuals through the half-sib progeny. The earliest form of half-sib recurrent selection was ear to row selection as a method of altering chemical composition of maize (Hopkins, 1899). Tannur and Smith (1987) suggested that half-sib family selection is highly effective in reducing inbreeding depression in maize populations.

The detailed knowledge of the genetic variability and identification of superior genotypes in a heterogeneous population is one of the major objectives of plant breeders and constitutes the first step towards developing a breeding program for this crop. Half-sib and full-sib families have been used and proved effective in the improvement of maize populations (Hallauer and Filho, 1988). Keeping in view the importance of recurrent selection and exploitation of variability present in the population, current researches conducted on 'half-sib families' recurrent selection with the objectives to compute various components of variances from the expected mean squares and to estimate broad sense heritability, selection differential, index of variation and expected responses to selection for a random sample of maize half-sib. It was found for the first time that Sarhad white

maize population "[Vikram (B11 x B37)] x Akbar" has considerable genetic variability and presents a remarkable potential for improvement via recurrent selection, which may give rise to considerable selection gain for various traits in future.

MATERIALS AND METHODS

This research was conducted at Experimental Research Farm of Agricultural University Peshawar, Khyber Pakhtunkhwa Province of Pakistan in summer 2008.

Plant material: Breeding material, comprised of 144 half-sib families derived from Sarhad White maize population"[Vikram (B11 x B37)] x Akbar", were developed at Cereal Crop Research Institute (CCRI) Pirsabak, Nowshera, Pakistan. These materials were then shifted to the Experimental Research Farm of Agricultural University Peshawar where all the field experi-ments were performed.

Experimental design: The experi-ment was laid out in an incomplete block lattice design of 12 x 12 size with two replications. Plant to plant and row to row distances were kept as 25 and 75 cm, respectively. Each family was grown in a single row of five meters length. The area per entry was $3.75 m^2$. Two seeds per hill were planted which were later on thinned to single plant.

Fertilizer application and data collection for selected parameters: Fertilizer was applied at the rate of 120-50 NP kg ha^{-1}. Standard cultural practices were adapted from sowing till harvesting of the crop. Data were recorded at regular intervals on days to 50 % tasseling, days to 50 % pollen shedding, days to 50 % silking, plant height (cm), ear height (cm), ear length (cm),kernel rows ear^{-1}, kernels row^{-1}, 1000 kernel weight (g), and grain yield (kg ha^{-1}). Data were recorded by visual inspection, ruler and electric weigh balance accordingly.

Statistical analysis: Data were statistically analyzed using the MStat-C (1991), a statistical package for the Analysis of Variance (ANOVA) to test the significance of families' means. Estimates of genotypic and pheno-typic components were calculated from the ANOVA and used to calculate heritability on entry mean basis following Carson et al., (2004) and Penny and Eberhat (1971) methods as given below:

Genotypic variance $(\sigma^2_g) = M_2 - M_1 / r$
Where:
M_1 = Error mean squares; M_2 = Genotypes/families mean squares; r = No of replications,   Phenotypic variance $(\sigma^2_p) = \sigma^2_g + \sigma^2_e / r$ h^2 (BS) = σ^2_g / σ^2_p

Selection differential was calculated as: $S = \mu HS - \mu$
Where   S = selection differential; μHS = Mean of the selected half-sib families
μ = population mean (comprising of all half-sib families)

Expected response (Re) was calculated as the product of selection differential (S) and heritability (h^2) $R_e = S \times h^2$

Genotypic and environmental variation coefficient was obtained as:

$CV_g = \sigma_g / ÿ \times 100$, $CV_e = \sigma_e / ÿ \times 100$

Where ÿ is the mean of half-sib families

Index of Variation (I.V), a relative measure of variability was calculated as:

$I.V = CV_g / CV_e$

RESULTS

Our results for the various important traits of half-sib families showed highly significant differences that show potential of half-sib families for genetic improvement of these traits. Traits that showed this genetic potential for further improvement include plant maturity traits, plant and ear height, ear length, kernel rows per ear, 1000-kernel weight and grain yield.

Maturity traits: Statistical analysis of the maturity traits i.e. days to 50% tasseling, 50% pollen shedding and 50% silking revealed highly significant diffe- rences among the half-sib families (Table-1). Heritability ranged from 0.72 to 0.88 for the maturity traits (Table 2), which indicated low environmental effects and the potential for further improvement of these traits in the current breeding materials. The index of variation ranged from 1.20 to 1.92 for the maturity traits (Table 2). Based on the heritability estimates and selec- tion differential the expected response to selection for 50% tasseling, 50% pollen shedding, and 50% silking was -0.03, -2.07 and 0.05, respectively (Table 3).

Table – 1: Mean squares and coefficient of variation for various traits in maize half-sib families

Trait	Mean squares		Coefficient of variation (CV %)
	Family	Error	
Days to tasseling	2.74**	0.779	1.65
Days to silking	4.94**	0.593	1.35
Days to pollen shedding	3.11**	0.806	1.63
Plant height (cm)	327.6**	189.69	7.80
Ear height (cm)	160.03**	82.592	11.0
Ear length (cm)	3.95**	1.206	7.00
Kernel rows cob^{-1}	2.31*	1.664	8.50
Kernels row^{-1}	18.38**	5.203	6.80
1000 kernel weight (g)	1508.21**	743.234	11.0
Grain yield (kg ha^{-1})	995953.8**	268428.06	13.8

* = Significant at 5 % level of probability **= Significant at 1% level of probability

Plant architectural traits (plant and ear height): In our research, plant and ear height revealed highly significant differences among the half-sib families (Table-1). Heritability estimates were moderate for plant and ear height and were 0.42 and 0.48, respectively. The index of variation for plant and ear height was 0.60 and 0.68 (Table 2) respectively, indicating low amount of relative variability. The expected response to selection for plant and ear height was 3.26 and 2.72 respectively (Table 3).

Ear length: Ear length was highly significantly different among the half-sib families (Table 1).High heritability (0.69) and index of variation (1.07) estimates were observed for ear length (Table 2).The expected response for ear length was 0.56 cm.

Table-2: Estimates of variance components, heritability ($h^2_{B.S}$), coefficient of variation, and index of variation (I.V) for various traits in maize half-sib families

Trait	σ^2_e	σ^2_g	σ^2_p	$h^2_{B.S}$	CVg %	CVe %	I.V
Days to tasseling	0.39	0.98	1.37	0.72	1.85	1.65	1.12
Days to silking	0.30	2.18	2.47	0.88	2.60	1.36	1.92
Days to Pollen shedding	0.40	1.15	1.56	0.74	1.96	1.64	1.20
Plant height (cm)	94.84	68.94	163.78	0.42	4.75	7.88	0.60
Ear height (cm)	41.30	38.72	80.02	0.48	7.97	11.64	0.68
Ear length (cm)	0.603	1.373	1.98	0.69	7.96	7.46	1.07
Kernel rows ear[-1]	0.832	0.323	1.16	0.28	3.78	8.59	0.44
Kernels row[-1]	2.602	6.589	9.19	0.72	7.73	6.87	1.13
1000 kernel wt (g)	371.62	382.49	754.10	0.51	7.99	11.14	0.72
Grain yield (kgha[-1])	134214.03	363762.87	497976.89	0.73	16.13	13.85	1.16

CVg = Genetic coefficient of variation, **CVe** = Environmental coefficient of variation

Kernel rows per ear: Statistical analysis of data regarding kernel rows ear[-1] showed highly significant differences among the half-sib families (Table1). Low Heritability (0.28) for kernel rows ear[-1] was observed among the half-sib families (Table 2). The expected responses for kernel rows ear[-1] and kernels row[1] estimates were - 0.08 and 1.31, respectively.

1000-kernel weight: Data regarding 1000-kernel weight showed highly significant differences among the half-sib families (Table 1). Heritability for 1000-kernel weight was 0.51 which is classified as moderate (Table 2). The expected response for 1000 kernel weight was 2.57 g (Table 3).

Grain yield: Statistical analysis revealed highly significant differences among half-sib families for grain yield (Table-1). High heritability (0.73) was observed for grain yield. Based on the selection differential (1233 kg ha^{-1}) and heritability of the trait (0.73) the expected response was 901 kg ha^{-1} (Table 2). The Index of variation was 1.16 (Table 3).

Table - 3: Population mean (μ), mean of the selected half-sib families (μHS), selection
differential (S), and expected responses (Re) for various traits **in** maize half-sib families

Trait	(μ)	μHs	S	Re
Days to tasseling	53.44	53.40	-0.04	-0.03
Days to silking	56.77	53.40	-3.37	-2.97
Days to Pollen shedding	54.86	54.93	0.07	0.05
Plant height (cm)	174.74	182.48	7.74	3.26
Ear height (cm)	78.05	83.67	5.62	2.72
Ear length (cm)	14.73	15.53	0.80	0.56
Kernel rows ear^{-1}	15.02	14.74	-0.29	-0.08
Kernels row^{-1}	33.20	35.03	1.83	1.31
1000 kernel weight (g)	244.74	249.80	5.06	2.57
Grain yield (kg ha^{-1})	3740.19	4973.61	1233.42	900.99

Genetic improvement of the existing Composite varieties or synthetics is vital for sustainable crop production especially in communities that heavily rely on subsistence agriculture. Open pollinated or synthetics provide comparable yield to poor famers and allow for greater genetic variability required for meeting the food security. In our current study an existing maize Composite Sarhad white "[Vikram (B11 x B 37)] x Akbar" was subjected to Intra-population half sib family recurrent selection to improve its genetic potential. High heritability, high index of variation estimates (I.V >1), for various traits indicates greater heterogeneity, genotypic difference among the tested half sib families. The improved recurrent population Sarhad white has the potential to recurrent selection and could be used in future maize breeding programs to extract new lines. The improved recurrent population may also be used by poor farmers to save production cost and moreover the seed could be used in future.

DISCUSSION

Plant breeders are interested in developing new genotypes having synchronized maturity, plant and ear height, ear length, kernel rows ear^{-1}, thousand kernel weight and grain yield. The maturity traits revealed highly significant differences among the half-sib families. Abedon and Taracy (1998) also observed significant differences for maturity traits using recurrent selection. These results are also in agreement with those of Noor et al. (2010) who also observed highly significant differences for days to 50% tasseling, 50% pollen shedding, and 50% silking while evaluating half-sib families in a maize variety 'Pahari'. In another study, index of selection and estimation of genetic parameters for different traits related to production and yield of vegetable corn were studied (Rodrigues et al., 2011). In our

research, heritability ranged from 0.72 to 0.88 for the maturity traits, which indicated low environmental effects and the potential for further improvement of these traits. Noor et al., (2010) also observed high heritability estimates for the maturity traits. Smalley et al., (2004) estimates heritability in maize by parent-offspring regression. Soleri and Smith (2002) also reported on rapid estimation of broad sense heritability of maize populations in Mexico. In Brassica though belong to different family similar results were obtained for estimating yield and yield components (Rameah et al., 2003). In a very recent study by Izadi-Darbandi et al., (2013), heritability estimates for different agronomic traits in Iranian Fennels were studied. These findings show that maturity traits are strong genetic control and could be exploited further for obtaining a more uniform maturity of the these important traits. Furthermore, high value of I.V>1 reflects possibility for further improvement of maturity traits.

Plant and ear height are important traits and of prime importance to breeders. Plant and ear height also have a great effect on production of successful maize crop. Increased height and placement of the ears above the middle of plant causes lodging. In our research, plant and ear height revealed highly significant differences among the half-sib families. These findings are in line with those of Paterniani et al., (2004).They also found significant differences for plant and ear height while evaluating 200 half-sib families in a maize composite-I-Mo. Heritability estimates were moderate for plant height and ear height. These results are in agreement with those of Noor et al., (2010) who also found moderate heritabilityfor plant height and for ear height.The index of variation for plant and ear height was also low for both plant and ear height, indicating low amount of relative variability. The expected response to selection for plant and ear height was high (3.26 and 2.72 respectively) and thus show high genetic variability. Peterniani et al., (2004) found similar results for index of variation of plant and ear height, indicating high genetic variability and possibility for selection. Andrade and Filho (2008) also obtained high index of variation, and observed high genetic variation for plant and ear height in half-sib family selection.

Ear length is another important yield contributing trait. In current study, ear length was highly significant among the half-sib families. Significant difference for ear length was also observed by Carlone and Russel (1989) while evaluating testcrosses of maize synthetics BSSS (Iowa Stiff Stalk Synthetic) lines. We found high heritability and index of variation estimates for ear length. In study performed by Mahmood et al., (2004), high heritability estimates were reported for ear length. We found the expected response for ear length as 0.56 cm that shows high heritability. Andrade and Filho (2008) also reported high heritability and index of variation for ear length. According to Rahman et al. (2007) shorter rows in a short ear

may not contribute to the total yield as compared to long rows in a long ear, showing that ear length is very important for obtaining high yield of maize crop.

In this research, data regarding kernel rows ear^{-1} showed highly significant differences among the half-sib families. Saleem et al., (2007) also observed highly significant differences among the genotypes evaluated for kernel rows ear^{-1}. However, low heritability for kernel rows ear^{-1} was observed among the half-sib families. Contrary to our results Mahmood et al., (2004) reported high heritability for this trait. The expected responses for kernel rows ear^{-1} and kernels row^{1} estimates were -0.08 and 1.31, respectively. Theoretically a greater number of rows ear^{-1} should result in higher yield. However, shorter rows in a short ear may not contribute to the total yield as compared to long rows in a long ear (Rahman et al., 2007).

Thousand kernel weights are considered to be an important parameter and contribute much to total yield. In current research 1000-kernel weight showed highly significant differences among the half-sib families. Significant differences for this trait were also observed by Rahman et al., (2007) who evaluated original and selected maize population for grain yield traits. Heritability for 1000-kernel weight was found as moderate. Contrary to our results, high heritability was reported by Sjiprihati et al., (2003). The expected response for 1000 kernel weight was 2.57 g.

Grain yield is one of the most important traits of food crops. Statistical analysis of the current research on maize half-sib families revealed highly significant differences among half-sib families for grain yield. Vales et al., (2001) also reported significant increase in grain yield due to selection. However, contrary to this Mikova et al., (2013) and Sughra et al., (2010) found that nitrogen fertilizer has more drastic effects on maize yield as compared to hybrids while Protic et al., (2013), in wheat reported major effects of genotype rather than the interaction effects of genotype x location, showing that genetically wheat can be improved significantly for yield and even for water stress (Sial et al., 2010). Based on the selection differential (1233 kg ha^{-1}) and heritability of the trait (0.73) the expected response was 901 kg ha^{-1}. Xiao et al., (2005) found high heritability estimates for grain yield. Vashistha et al., (2013) observed high estimates of heritability for plant height, ear girth, and ear height. They also found high to moderate heritability for biological yield, grain yield per plant, plant height and ear height. Greater genetic proportion of variation among the half-sib families shows greater genetic variability and potential for recurrent selection to improve grain yield and yield related traits simultaneously. These findings suggest that direct selection for grain yield would be effective in improving maize population provided heritability of secondary characters related to yield is high.

CONCLUSION

High estimates of heritability and index of variation (I.V >1) indicate favorable situation and existence of sufficient amount of genetic varia-bility among the half-sib families for further improvement and potential for recurrent selection.Here we report for the first time that Sarhad white maize population"[Vikram (B11xB37)] x Akbar" has considerable genetic varia-bility and presents a remarkable potential for improvement via recurrent selection, which may give rise to considerable selection gain for various traits. Sarhad white "[Vikram (B11 x B37)] x Akbar" maize improved population could be used as a base population for deri-vation of inbred lines and have the potential to be improved further for yield and yield associated traits.

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