www.biodicon.com Biological Diversity and Conservation

ISSN 1308-5301 Print; ISSN 1308-8084 Online 3/1 (2010) 121-127

Response to selection for grain yield under maydis leaf blight stress environment in maize (*Zea mays*)

Ibni amin KHALIL [1], Hidayat-UR-RAHMAN [1], Durres HAHWAR [1], Iffat NAWAZ [1], Hidayat ULLAH [*1], Farhan ALI [1]

[1] Department of Plant Breeding and Genetics, NWFP Agricultural University Peshawar, Pakistan

Abstract

Maydis leaf blight (MLB), caused by *Bipolaris maydis*, is one of the most important diseases in maize. The objectives of this study were to quantify the progress for maydis leaf blight resistance improvement by estimating selection differential, expected and observed responses to selection after two cycles of S_1 line recurrent selection, and to estimate heritability for various morphological and yield traits in "Azam" composite maize population. This study was conducted at the research farm of Agricultural University, Peshawar, Pakistan during summer 2006 and 2007. In cycle-3 about one hundred S_1 lines while in cycle-4 196 S_1 lines of maize population Azam were evaluated under epiphytotic conditions along with their progenies in lattice square design with two replications. Highly significant variations were observed among the S_1 lines for grain yield, MLB, plant height, ear height, ear length, kernel rows cob^{-1}, and maturity traits in two cycles. In cycle-3 the expected and observed responses for grain yield (432, 2144 kg ha^{-1}), MLB (-0.53, -0.65), plant height (1.65, 28cm), ear height (-0.43, 10 cm), ear length (0.78, 5 cm), kernel rows cob^{-1} (-0.29, 2), pollen shedding (-0.21, -5 days) and silking (-0.09, -4 days) were observed, while in cycle-4 expected and observed responses were (715, 2762 kg ha^{-1}), (-0.01, -0.13), (1.15, 41 cm), (0.44, 23 cm), (1.17, 3 cm), (0.07, 1), (-1.23, -2 days) and (-1.39, -1 days) for the above traits, respectively. In both cycles the heritability values were estimated for grain yield (0.50, 0.64), MLB (0.84, 0.52), plant height (0.62, 0.79), ear height (0.63, 0.47), ear length (0.58, 0.55), kernel rows cob^{-1} (0.63, 0.62), pollen shedding (0.83, 0.83) and silking (0.72, 0.82). The increased performance of the progenies of selected S_1 lines manifests the efficiency of breeding program and suggests that S_1 line recurrent selection would be the most efficient method for improving MLB resistance and grain yield simultaneously in maize population Azam.

Key words: *Bipolaris maydis, recurrent selection, observed response, heritability, Corn*

1. Introduction

Maize (*Zea mays* L.) is extensively grown in temperate, subtropical and tropical regions of the world. Its range of adaptation stretches from 50° N to 40° S latitude and can be grown at an altitude from sea level to 3300 meters above sea level (Shah *et al*., 2006). In Pakistan, during 2006-07, it was cultivated on 1016.9 thousand hectares with a total production of 3188.4 thousand tons and productivity of 3037 kg ha^{-1}. In NWFP maize was grown on 516.1 thousand hectares with total production of 918.6 thousand tons and productivity of 1780 kg ha^{-1} (MINFAL, 2007).

Despite its high yield potential, one of the major limiting factors to maize grain yield is its sensitivity to several diseases. Southern corn leaf blight (SCLB) or maydis leaf blight (MLB) caused by *Bipolaris maydis* (*Drechslera maydis*; telomorph: *Cochliobolus heterostrophus*) occurs widely on maize (Bekele and Sumner, 1983). *Bipolaris maydis* is a member of the ascomycetes, the sac fungi which produces a toxin that attacks the mitochondria and destroys the plants ability to capture energy from metabolism. Three races of *H. maydis* have been described (Carson, 1998; Wei *et al*., 1988). Race 'O' is considered the most common and indigenous throughout most areas where SCLB occurs. This infects the leaves only, forms small (0.6 x 2.5 cm), tan and parallel-side lesions with buff or brown borders. On the other hand, race T, the cause of the 1970 SCLB epidemic in North America, is specifically virulent on Texas male sterile cytoplasm (cmsT) maize due to its ability to produce a polypeptide toxin (T toxin) to which cmsT maize is

[*] *Corresponding author* / Haberleşmeden sorumlu yazar: shabkadar@yahoo.com

 BioDiCon. 127-0210

sensitive (Carson, 1998; Levings and Siedow, 1992). It attacks all above ground parts of maize plant. The lesions in this case are spindle shaped and surrounded by green or chlorotic halos (Agrios, 1997; Rahman *et al.,* 2005). Race C of *H. maydis,* specifically virulent on C male sterile cytoplasm (cmsC) maize, has been reported from China, but is not known to occur elsewhere (Gao *et al.,* 2005; Wei *et al.,* 1988). MLB is also prevalent in the maize growing regions of NWFP and accounts for about 20% or sometime even more yield losses to the crop in Pakistan (Hafiz, 1986).

Keeping in view the importance of maydis leaf blight disease, an experiment was conducted in field under epiphytotic conditions for screening and evaluation of S_1 lines against maydis leaf blight. The objectives of the study were to quantify the progress for maydis leaf blight resistance improvement by estimating expected and observed responses to selection after two cycles of S_1 line recurrent selection, and to estimate heritability for various morphological and yield traits in Azam maize composite population.

2. Materials and methods

2.1. Experimental material's development

The field experiment was conducted at Agricultural Research Farm of NWFP Agricultural University Peshawar during summer 2006 and 2007 (July-October). For S_1 lines production, Azam maize population was grown over an area of 600 m^2 in spring (February-June) 2006 and 2007. Plant spacing between rows was 0.75 m, while 0.25 m was within the row. Two seeds $hill^{-1}$ were planted, which were later thinned to maintain one plant $hill^{-1}$, when the plants were 10-15 cm tall. Standard cultural practices were applied to get healthy and vigorous plants for selfing. At maturity the selfed ears were individually harvested, shelled and numbered separately. Half of the seed of each S_1 line was planted in replicated trial for evaluation in summer season (2006), while the other half was kept as a remnant for recombination phase. Square lattice design was used in the field for S_1 lines evaluation. The recombined seed were used as a base population for next cycle. The S_1 lines production and planting methodology in the next cycle was the same as discussed earlier.

2.2. Inoculation procedure

The S_1 lines were planted in replicated trial along with local checks. All the lines were inoculated with spores of *H. maydis* along with their respective checks, at four to six leaves stage. The inoculum was prepared by grinding leaves infected with maydis leaf blight collected from previous crop (Shah *et al*. 2006; Gao *et al*. 2005; Lambert and White, 1997; Sumner and Littrell, 1973).

2.3. Data Recording

2.3.1 Disease ratings

Whole plots were visually rated four times in both the cycles for percent MLB severity beginning at two weeks post anthesis with one week interval (Shah *et al*., 2006; Carson *et al*,, 2004; Carson, 1998). For recording disease data a scale of 0-5 was used following the CIMMYT procedure, i.e. 0 for no lesion and 5 for heavily blighted leaves. Rating of 0.0-1.4 were considered resistant, 1.5-2.4 moderately resistant and 2.5-5.0 susceptible (CIMMYT, 1985), As the disease reaction was rather uncertain to fall exactly in each of the mentioned classes, an arbitrary gradation of 10 classes scale i.e. 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5 and 5.0 was used to measure the disease severity more accurately (Shah *et al*. 2006).

2.3.2 Grain yield (kg ha^{-1})

After physiological maturity (black layer formation at hilum), ears from each entry were harvested to obtain yield data. Grain yield (kg ha^{-1}) was obtained using the following formula relationship (Carangal *et al., 1971).*

$$\text{Grain yield (kg ha}^{-1}) = \frac{\text{F.wt.} \times (100\text{-MC}) \times 0.80 \times 10{,}000\text{m}^2}{(100\text{-}15) \times 3.37\ \text{m}^2}$$

2.3.3 Plant height (cm)

Height of each plant was measured with the help of a measuring rod as the distance from ground level to the auricle of the flag leaf (Guzman and Lamkey, 2000) on 10 randomly selected plants was then converted to per plot by taking their averages.

2.3.4 Ear height (cm)

It was measured as the distance from soil to the node bearing primary ear (uppermost) as mentioned by Guzman and Lamkey (2000) on randomly selected plants.

2.3.5 Ear length (cm)

Length of the above randomly chosen ears from each plot was measured with measuring tap and recorded as average ear length (John, 1991).

2.3.6 Number of kernel rows ear^{-1}

Grain rows of randomly selected ears mentioned above were counted and recorded as number of kernel rows ear^{-1} for each plot.

2.3.7 Days to 50% pollen shedding

In each plot the number of days from planting to 50% pollen shedding was recorded when pollen shedding started after dehiscence of anthers on central branch of the tassel on 50 % plants in a plot (Khan, 1986 and Ihsan *et al*., 2005).

2.3.7 Days to 50% silk emergence

Silking date was recorded when the first day silks became visible on the topmost ear of at least 50% of plants in a plot (Tollenaar *et al*., 2004 and Lee *et al*., 2005). The number of days from planting to 50% silk emergence was then recorded as days to 50 % silk emergence (Hinze and Lamkey, 2003 and Khan *et al*., 2004).

2.4 Statistical analysis

Analysis of variance was conducting according to Steel and Torrie (1984). Microsoft Excel program was used for calculation of expected and observed responses, and graphs. Estimates of genotypic and phenotypic variance components were calculated from ANOVA to estimate heritability on an entry mean basis (Carson *et al.*, 2004; Penny and Eberhart, 1971).

3.Results and discussion

3.1. Grain yield (kg ha^{-1})

Grain yield exhibited highly significant differences (P<0.01) among S_1 lines in both the cycles (Table 2). It was found that mean grain yield in cycle-3 (3629 kg ha^{-1}) was comparatively less than that of cycle-4 (4105 kg ha^{-1}). Likewise the average grain yield of the selected S_1 lines of cycle-3 was 4491 kg ha^{-1} while in cycle-4 it was 5223 kg ha^{-1}. Whereas the grain yield obtained from the progenies of the selected S_1 lines in both the cycles was 5773 and 6867 kg ha^{-1} respectively (Table 1). With the expected responses in cycle-3 (432 kg ha^{-1}) and cycle-4 (715 kg ha^{-1}), prediction were made which were confirmed from the resultant observed responses 2144 and 2762 kg ha^{-1} (Table 20) in both the cycles respectively. Our results are in agreement with those of De Leon *et al.* (1993) who also reported highly significant increase in grain yield i.e. 507 kg cycle^{-1}. Similarly Vales *et al.* (2001) also reported significant increase in grain yield due to selection. Heritability for the said trait in cycle-3 and cycle-4 were 0.50 and 0.64, respectively (Table 2). The heritability values for grain yield were normally low because of the large number of genes involved and the high level of environmental interaction (Welsh, 1981). The increased performance of the progenies of the selected S_1 lines manifests both the efficiency of breeding program and the heterosis after recombination of the selected S_1 lines.

Table 1. Mean values for population (µ), Selected S_1 lines (µS), Progenies (µP) and Check for different traits in two cycles of S_1 line recurrent selection.

Traits	Cycle-3				Cycle-4			
	µ	**µS**	**µP**	**check**	**µ**	**µS**	**µP**	**check**
Yield (kg ha^{-1})	3629	4491	5773	5117	4105	5223	6867	6603
Maydis leaf blight	1.15	0.5	0.5	0.625	0.63	0.60	0.5	1.5
Plant height (cm)	131	134	159	151	129	130	170	183
Ear height (cm)	57	56	67	78	60	61	83	98
Ear length (cm)	11	13	17	14	13	15	17	18
Kernel rows ear^{-1}	14	14	16	13	13	14	14	14
Days to pollen shedding	52	52	47	48	54	53	52	52
Days to silking	52	52	48	48	55	53	54	54

2.3. Maydis leaf blight

Maydis leaf blight (MLB) caused by *Bipolaris maydis* occurs widely on maize (Bekele and Sumner 1983). Recurrent mass and S_1 family selection for quantitative disease resistance in corn (*Zea mays* L.) have been highly effective. Statistical analysis exhibited highly significant variations (P<0.01) for maydis leaf blight (MLB) among S_1 lines in both the cycles (Table 2). The mean value for MLB in cycle-3 was 1.15 while in cycle-4 it was 0.63 (Disease scale 0.0-5.0). The lower disease score in cycle-4 as compared with cycle-3 reflects the genetic improvement of the population against maydis leaf blight disease as well as efficacy of the recurrent selection method. These results are supported by those reported by Ceballos *et al*, (1991) and De leon *et al.* (1993), who also observed reduction in maydis leaf blight severity in advanced cycles of recurrent selection in maize populations. The average rate of MLB in the selected lines of cycle-3 was 0.5 while in cycle-4 it was 0.60. On the other hand MLB observed in the progenies of both the cycles was 0.5 (Table 1). In cycle-3 the expected response for MLB was -0.53, while the observed response was -0.65. Likewise in cycle-4 the expected response for MLB was -0.01 while the observed response was -0.13. In both cycles the responses were in desired direction. These results are also supported by those of Jinhyon and Russell (1969) who reported reduction in mean disease score for stalk rot from 3.7 to 1.7 with three cycles of S_1 line recurrent selection. Heritability for the said trait in cycle-3 and cycle-4 were 0.84 and 0.52 respectively (Table 2). The high heritability and negative value of expected responses in both cycles also predicted reduction in disease severity. The observed responses for MLB in progenies of selected S_1 lines of both the cycles were also reduced, thereby exhibiting the efficiency of selection. Disease progress for population, selected S_1 lines, progenies of selected S_1 lines and check in both the cycles, cycle-3 and cycle-4, are graphically presented in Figure.1 and 2 respectively, showing increasing infestation of MLB severity.

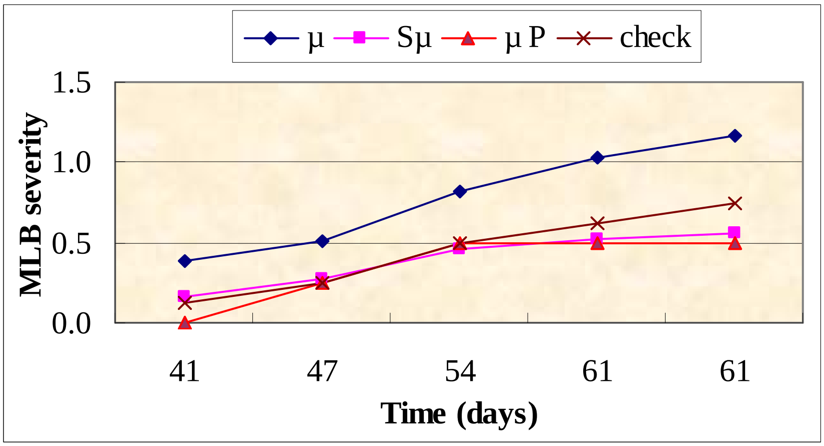

Figure 1. Response of population mean (µ), selected $S_{1's}$ mean (Sµ), progenies mean (µP) and check to MLB severity in cycle-3.

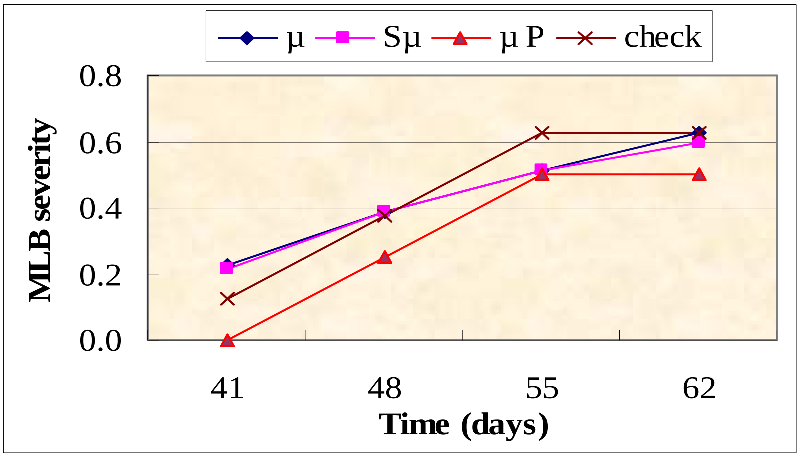

Figure 2. Response of population mean (µ), selected $S_{1's}$ mean (Sµ), progenies mean (µP) and check to MLB severity in cycle-4.

2.4. Morphological characteristics

Data showed highly significant variations (P<0.01) for plant and ear height among the S_1 lines in both the cycles (Table 2). Abedon and Tracy (1998) reported significant differences for plant and ear height while using full sib recurrent selection in maize. The average plant height of the population in cycle-3 was 131 cm while in cycle-4 it was 129 (Table 1). Mean plant height attained by the selected S_1 lines in cycle-3 was 134 cm while in cycle-4 it was 130 cm. In both the cycles the progenies attained plant height of 159 cm and 170 cm, respectively in cycle-3 and cycle-4 (Table

1). In cycle-3, the expected response for plant height was 1.65 while the observed response was 28. In cycle-4 the expected response for plant height was 1.15 while the observed response was 41 (Table 2). It was found that the observed responses in both the cycles were far greater than the expected responses for plant height which are in close conformity with those reported earlier by Devey and Russell (1983) who also observed significant increase in plant height after conducting seven cycles of S_1 recurrent selection in maize. Heritability for the said trait in cycle-3 and cycle-4 were 0.62 and 0.79 respectively, (Table 2). Mihaljevic *et al*. (2005) obtained high heritability values (0.90) for plant height. The greater the heritability of a particular trait, the lesser will be the environmental effect.

As for as the ear height of population is concerned, in cycle-3 it was 57 cm while in cycle-4 it was 60 cm. Mean ear height observed in the selected S_1 lines in cycle-3 was 56 cm while in cycle-4 it was 61 cm. In both the cycles the progenies attained the ear height of 67 cm and 83 cm respectively (Table 1). The expected response for ear height was -0.43 while the observed response was 10 in cycle-3 whereas in cycle-4 the expected response for ear height was 0.44 while the observed response was 23. Heritability for ear height in cycle-3 and cycle-4 estimated were 0.63 and 0.47, respectively (Table 2). The observed responses in both the cycles for plant (28 cm, 41 cm) and ear height (10 cm, 23 cm) in the progenies of the selected S_1 lines were increased significantly after two cycles of S_1 line recurrent selection. However, Weyhrich *et al*. (1998) reported significant decrease (6.52 cm) in ear height using S_1 recurrent selection. The increased in plant and ear height in the progenies could be attributed to the expression of heterosis after recombining the selected S_1 lines.

2.5. Ear characteristics

Data concerning ear length and kernel rows ear^{-1} showed highly significant differences (P<0.01) for ear length and kernel rows ear^{-1} among the S_1 lines in both the cycles (Table 2). The mean ear length recorded for population in cycle-3 was 11 cm while in cycle-4 it was 13 cm. Ear length observed in the selected S_1 lines in cycle-3 was 13 cm while in cycle-4 it was 15 cm. For the progenies in both the cycles ear length recorded was 17 cm (Table 1). In cycle-3 the expected response for ear length was 0.78 while the observed response was 5 whereas in cycle-4, the expected and observed responses for ear length were 1.17 and 3, respectively. Heritability for the said trait in cycle-3 and cycle-4 were 0.58 and 0.55, respectively (Table 2).

Average kernel rows ear^{-1} in cycle-3 was 14 while in cycle-4 it was 13. In the selected S_1 lines of both the cycles the kernel rows ear^{-1} were 14. Similarly in the progenies of both the cycles, kernel rows ear^{-1} were 16 and 14, respectively (Table 1). The expected response for kernel rows ear^{-1} was -0.29 while the observed response of 2 in cycle-3 while in cycle-4 the expected and observed responses for kernel rows ear^{-1} were 0.07 and1, respectively. Heritability for the said trait in cycle-3 and cycle-4 were 0.63 and 0.62, respectively (Table 2). Theoretically, a greater number of rows ear^{-1} should result in higher yield. However, short rows in a short ear may not contribute to the total yield as much as long rows in a long ear, (Rahman *et al*., 2005). As an increase of (0.78 and 1.17 cm) and (-0.29 and 0.07 kernel rows ear^{-1}) was predicted from the expected responses in both the cycles for ear length and kernel rows ear^{-1}, respectively, hence the observed responses in both the cycles for ear length (5 and 3 cm), and kernel rows ear^{-1} (2 and 1) confirmed improvement in both the traits after two cycles of S_1 line recurrent selection.

Table 2. Mean squares (MS), selection differential (S), expected (R_e) and observed (R_o) response and Heritability for different traits in two cycles of recurrent selection in maize composite population Azam, evaluated in 2006 and 2007.

Traits	**Cycle-3**					**Cycle-4**				
	MS	**S**	R_e	R_o	h^2_{BS}	**MS**	**S**	R_e	R_o	h^2_{BS}
Grain yield (kg ha^{-1})	1911093.8**	862	432	2144	0.50	1501733.1**	1119	715	2762	0.64
Maydis leaf blight	0.572**	-0.64	-0.53	-0.65	0.84	0.083**	-0.03	-0.01	-0.13	0.52
lant height (cm)	534.62**	2.66	1.65	28	0.62	534.62**	1.46	1.15	41	0.79
Ear height (cm)	314.64**	-0.68	-0.43	10	0.63	89.969**	0.92	0.44	23	0.47
Ear length (cm)	5.328**	1.35	0.78	5	0.58	4.028**	2.13	1.17	3	0.55
Kernel rows ear^{-1}	3.931**	-0.46	-0.29	2	0.63	4.266**	0.12	0.07	1	0.62
Days to pollen shedding	7.908**	-0.25	-0.21	-5	0.83	7.329**	-1.48	-1.23	-2	0.83
Days to Silking	10.719**	-0.12	-0.09	-4	0.72	8.325**	-1.68	-1.39	-1	0.82

** = Significant at 1% level of probability

2.6.Maturity characteristics

Data concerning days to pollen shedding and silking revealed highly significant variations (P<0.01) among S_1 lines in both the cycles (Table 2). Abedon and Tracy (1998) also observed significant differences for maturity traits using S_1 line recurrent selection. The selected S_1 lines of both the cycles took 52 and 53 days, respectively to start pollen shedding. Similarly in the progenies of both cycles days to pollen shedding were 47 and 52, respectively (Table

1). In cycle-3 the expected response for days to pollen shedding was -0.21 while the observed response was 5. In cycle-4 the expected response for days to pollen shedding was -1.23 while the observed response was -2. Similar estimates of heritability (0.83) for days to pollen shedding were observed in both the cycles indicating that this trait was less influenced by the environment.

The mean values recorded for days to silking in cycle-3 and cucle-4 were 52 and 55, respectively. Selected S_1 lines in both the cycles, cycle-3 and cycle-4, took 52 and 53 days, respectively for days to silking. In case of progenies cycle-3 and cycle-4 completed silking in 48 and 54 days, respectively (Table 1). In cycle-3 the expected response for days to silking was -0.09 while the observed response was -4. In cycle-4 the expected response for days to silking was -1.39 while the observed response was -1. Heritability estimates observed for days to silking in cycle-3 and cycle-4 were 0.72 and 0.82, respectively (Table 2). High heritability (0.85) for the same trait in testcross of BSK(HI)C8 was recorded by Mulamba *et al*. (1983). Based upon negative magnitudes of expected responses, decrease in days was expected for maturity traits in progenies of selected S_1 lines in the both cycles. As per expectation, decrease in days was observed for days to pollen shedding and silking in the progenies of the selected S_1 lines of cycle-3 and cycle-4. Using recurrent selection for resistance to *Exserohilum turcicum* in eight subtropical maize populations, Ceballos *et al*. (1991) reported a significant decrease in maturity traits.

3. Conclusions

These results suggest that S_1 line recurrent selection would be the most efficient method for improving MLB resistance and grain yield simultaneously in maize population Azam.

References

Abedon, B.G., and W.F. Tracy. 1998. Direct and indirect effects of full-sib recurrent selection for resistance to common rust (*Puccinia sorghi* schw.) in three sweet corn populations. Crop Sci. 38: 56-61.

Agrios, G.N. 1997. Plant pathology. 4th Edition. Academic press, San Diego and London.

Bekele, E., and D.R. Sumner. 1983. Epidemiology of southern corn leaf blight in continuous corn culture. Plant Disease 67: 738-742.

Carangal, V.R., S.M. Ali, A.F. Koble, E.H. Rinke and J.C. Sentz. 1971. Comparison of S_1 with testcross evaluation for recurrent selection in maize. Crop Sci. 11:658-661.

Carson, M.L. 1998. Aggressiveness and presentation of isolates of *Cochliobolus herterostrophus* from North Carolina. Plant Disease. 9(82): 1043-1047.

Carson, M.L., C.W. Stuber, and M.L. Senior. 2004. Identification and mapping of quantitative trait loci conditioning resistance to southern leaf blight of maize caused by *Cochliobolus herterostrophus* race O. Phytopathol. 94: 862-867.

Ceballos, H., J.A. Deutsch, and H. Gutierrez. 1991. Recurrent selection for resistance to *E. turcicum* in eight sub-tropical maize populations. Crop Sci. 31: 964-971.

CIMMYT. 1985. Managing trials and reporting data for CIMMYT's International Maize Testing Program. CIMMYT, El Batan, Mexico.

De Leon, G. Granados, R.N. Wedderburn, and S. Pandey. 1993. Simultaneous improvement of downy mildew resistance and agronomic traits in tropical maize. Crop Sci. 33: 100-102.

Devey, M.E., and W.A. Russell. 1983. Evaluation of recurrent selection for stalk quality in a maize cultivar and effects of other agronomic traits. Iowa State J. Res. 58:207-219.

Gao, Z.S., H.W. Cai, and G.H. Liang. 2005. Field assay of seedling and adult plant resistance to southern leaf blight in maize. Plant Breeding. 124: 356-360.

Guzman, P.S. and K.R. Lamkey. 2000. Effective population size and genetic variability in the BS11 maize population. Crop Sci. 40(2): 338-346.

Hafiz, A. 1986. Plant diseases. Pak. Agric. Res. Council, Islamabad. 52 pp.

Hinze, L.L. and K.R. Lamkey. 2003. Absence of epistasis for grain yield in elite maize hybrids. Crop Sci. 43:46-56.

Ihsan, H., I.H. Khalil, H. Rahman and M. Iqbal. 2005. Genotypic variability for morphological and reproductive traits among exotic maize hybrids. Sarhad J. Agri. 21 (4): 599-602.

Jinhyon, S., and W.A. Russel. 1969. Evaluation of recurrent selection for stalk rot resistance in an open pollinated variety of maize. Iowa Stat J. Sci. 43: 229-237.

John, H.P. 1991. Hybrid genetic complement and corn plant DK570. Dekalb Genetics Corporation, IL, USA.

Khan, K. 1986. Study of different varieties of maize under traditional and modified management practices in Swat, NWFP. M.Sc. (Hons) Thesis, Deptt. Pl. Br. & Gen. NWFP Agri. Uni. Peshawar.

Khan, K., F. Karim, M. Iqbal, H. Sher and B. Ahmad. 2004. Response of maize varieties to environments in two agro-ecological zones of NWFP: Effects on morphological traits. Sarhad J. Agri. 20 (3): 395-399.

Lambert, R.J., and D.G. White. 1997. Disease reaction changes from tandom selection for multiple disease resistance in two maize synthetics. Crop Sci. 37: 66-69.

Lee, E.A., a. Ahmadzadeh and M. Tollenaar. 2005. Quantitative genetic analysis of the physiological processes underlying maize grain yield. Crop Sci. 45(3):981-987.

Levings, C.S., and J.N. Siedow. 1992. Molecular basis of disease susceptibility in the Texas cytoplasm of maize. Plant Mol. Biol. 19: 135-147.

Mihaljevic, R.C., C.C. Schoon, H.F. Utz, and A.E. Melchinger. 2005. Correlation and QTL correspondence between line per se and testcross performance for agronomic traits in four populations of European maize. Crop Sci. 45: 114-112.

MINFAL. 2007. Agriculture Statistics of Pakistan. Ministry of Food, Agric. and Livestock, Econ. Wing, Islamabad.

Mulamba, N.N., A.R. Hallaeur, and O.S. Smith. 1983. Recurrent selection for grain yield in a maize population. Crop Sci. 23: 536-540.

Penny, L.H., and S.A. Eberhart. 1971. Twenty years of reciprocal recurrent selection with two synthetic varieties of maize (*Zea mays* L.). Crop Sci. 11: 900-903.

Rahman, H., F. Raziq, and S. Ahmad. 2005. Screening and evaluation of maize genotypes for southern leaf blight resistance and yield performance. Sarhad J. Agric. 2(21): 231-235.

Shah, S.S., H. Rahman, I.H. Khalil, and A. Rafi. 2006. Reaction of two maize synthetics to maydis leaf blight following recurrent selection for grain yield. Sarhad J. Agric. 2(22): 263-269.

Steel, R.G.D., and J.H. Torrie. 1984. Principles and Procedures of Statistics: A Biometrical Approach, 2^{nd} Ed., McGraw Hill Book Co., New York.

Sumner, D. R., and R. H. Littrell. 1973. Influence of tillage, planting date, inoculum survival, and mixed populations on epidemiology of southern corn leaf blight. Phytopathol. 64: 168-173.

Tollenaar, M., A. Ahmadzadeh and E.A. Lee. 2004. Physiological basis of heterosis for grain yield in maize. Crop Sci. 44:2086-2094.

Vales, M.I., R.A. Valar, P. Revilla, and A. Ordas. 2001. Recurrent selection for grain yield in two Spanish maize synthetic populations. Crop Sci. 41: 15-19.

Wei, J.K., K.M. Lui, J.P. Luo, Y.O. Lee, and Standelman. 1988. Pathological and physiological identification of race ‘C’ of *Bipolaris maydis* in China. Phytopathol. 75: 550-554.

Welsh. J. R. 1981. Fundamentals of plant breeding. John Wiley and Sons. Inc. pp 134-135.

Weyhrich, R.A., K.R. Lamkey, and A. R. Hallauer. 1998. Effective Population Size and Response to S_1-Progeny Selection in the BS11 Maize Population. Crop Sci. 38:1149–1158.

(Received for publication 29 January 2009; The date of publication 01 April 2010)