

## Response of Two Maize Populations to Reciprocal Recurrent Selection in a High-yield Environment<sup>1</sup>

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**Abstract:** A selection program using reciprocal recurrent selection procedures in maize (*Zea mays* L.) was developed. Intra- and interpopulation selection procedures were used for two maize populations BS10 and RSSSC. Intrapopulation selection procedures included phenotypic mass selection for multiple leaf and multiple stalk-rot disease resistance and S<sub>1</sub> family selection for grain yield in a high-yield environment. Interpopulation improvement involved selection of testcrosses of S<sub>1</sub> family × inbred tester in a high-yield environment. Evaluations of populations *per se*, population crosses and populations × testers for response to three cycles of selection for grain yield were conducted at four environments. Evaluation of populations *per se* and population crosses for response to three cycles of selection for multiple leaf disease and multiple stalk-rot resistance was conducted at disease nursery in 1985. The results indicate that selection response was consistent among environments. Gain from selection was satisfactory in populations *per se*, population crosses and populations × testers for grain yield, multiple leaf disease resistance and multiple stalk-rot resistance. Linear response to three cycles of selection for grain yield for BS10, RSSSC, BS10 × RSSSC, BS10 × B37, and RSSSC × B79 were: 0.95, 0.69, 0.65, 0.65 and 0.24 Mg/ha/cycle, respectively. The rates of gain for grain yield obtained in the present study compare favorably with published reports. Linear response for stalk lodging for BS10, BS10 × RSSSC and BS10 × B37 were: -9.0, -5.4 and -3.5%/cycle, respectively. All populations *per se*, population crosses and populations × testers showed significant increase in penetrometer reading. Increase in plant height and ear height were observed for RSSSC, BS10 × RSSSC and RSSSC × B79. Population BS10 showed an increase in 300-kernel weight and kernel number per ear, and a decrease in ear number per 100 plants. Population RSSSC only showed an increase in 300-kernel weight. Three cycles of selection slightly increased grain moisture in BS10 and BS10 × B37. This result indicates the procedures of selection in a high-yield environment are beneficial in improving grain yield, multiple disease resistance and stalk lodging resistance in maize populations *per se* and their hybrids.

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## INTRODUCTION

Stalk lodging accounts for a large part of annual yield losses in corn. Stalk-rots caused by *Diplodia maydis* (Berk.) Sacc., *Gibberella zeae* (Schw.) Petch., *Fusarium moniliforme* Sheld. and *Collectrichum graminicola* (Ces.) Wils. are a major component of stalk lodging. In population improvement work, various recurrent selection procedures were effective for stalk-rot resistance. <sup>(13,20,23,24,30)</sup>

Maize leaf blights caused by *Exserohilum turcicum* (Pass.) Leonard & Suggs, *Bopolaris maydis* (Nisik.) Shoemaker and *Colletrichum graminicola* (Ces.) Wils. not only affected grain yield but allowed for predisposition to stalk-rot <sup>(5)</sup>. Jenkins *et al.* <sup>(12)</sup> found that recurrent selection was an effective breeding method for concentrating genes for resistance to *Exserohilum turcicum*. Compared to half-sib and S<sub>1</sub> family selection for resistance to northern corn leaf blight, Diplodia stalk-rot, and anthracnose leaf blight and stalk-rot, Miles *et al.* <sup>(23,24)</sup> found mass selection would be the most efficient method of improving resistance to these diseases in corn populations.

In addition to direct response, correlated changes in other agronomic traits usually accompany population improvement. Correlated changes varied for different selection methods, objectives and materials. Selection for high grain yield is usually accompanied with an increase in ear number per plant <sup>(19,25,26)</sup>, plant height <sup>(19)</sup>, ear height and grain moisture <sup>(6,19)</sup>. No change in ear height or grain maturity was reported by Eberhart *et al.* <sup>(4)</sup>. However, a decrease in ear height has been reported by Moll and Stuber <sup>(25)</sup> and Moll *et al.* <sup>(26)</sup>.

Martin and Russell <sup>(20,21)</sup> reported three cycles of recurrent selection for stalk-rot resistance in BS1 population caused a significant decrease in grain yield, plant height and field stalk lodging. Jinahyon and Russell <sup>(13,15)</sup> showed selection for stalk-rot resistance in a Lancaster open-pollinated population significantly increased plant height, ear height, stalk lodging resistance and grain moisture, but did not change in grain yield. Miles *et al.* <sup>(23)</sup> reported mass selection for resistance to four diseases (northern leaf blight, Diplodia stalk-rot, and anthracnose leaf blight and stalk-rot) would be very effective in improving disease resistance in corn populations and that such improvement would not affect yield potential of the populations if adequate effective population size is maintained.

Thompson <sup>(33)</sup> suggested rind penetrometer measurements as a non-destructive method for improving stalk strength in the field. Penetrometer readings were negatively correlated with stalk-rot rating <sup>(20,34,37)</sup>, and leaf blight infection <sup>(37)</sup>. Rind penetrometer measurements were highly correlated with total stalk lodging resistance <sup>(20,33,34)</sup>. Stalk lodging has been reduced by using recurrent selection to reduce plant and ear height <sup>(1,15)</sup>.

The primary objectives of this research were: (1) to evaluate direct response to selection for grain yield, multiple leaf disease resistance and multiple stalk-rot resistance; and (2) to evaluate concomitant changes in field stalk lodging and other agronomic traits.

## MATERIALS AND METHODS

### Experimental Material

Two synthetic cultivars were used in this study: RSSSC, a version of Stiff Stalk Synthetic as described by Kauffmann and Dudley<sup>(16)</sup> and Iowa Two-Ear Synthetic (BS10) described by Hallauer<sup>(8)</sup>. Cycle-4 of BS10 from Hallauer's reciprocal full-sib selection program was used as the base population in this study. Based on the data from diallel crosses of eight synthetics and other considerations BS10 and RSSSC were selected to initiate a reciprocal recurrent selection in a high-yield environment (HYE). The general combining ability effects of BS10 and RSSSC were high for grain yield and stalk lodging<sup>(17,18)</sup>.

### Experimental Management Practice

The experiments were conducted in four environments: HYE1, HYE2, UNE1 and UNE2. The HYE1 was located at the Agronomy-Plant Pathology Farm of the University of Illinois at Urbana, Illinois. The soil type of this field is a Flanagan fine silty-loam (montmorillonitic mesic Aquic Argiudolls). A crop rotation of maize and soybean (*Glycine max* (L.) Merrill) is used each year. Maize was planted on 23 April, 1985 and grown in a plot with two 4.6m rows and plant density of 81,785 plants/ha. A preplant application of herbicide was used with no row cultivation during the growing season. The fall application of fertilizer has included 333 kg/ha of potassium ( $K_2O$ ) and phosphorus ( $P_2O_5$ ). Prior to planting 250kg/ha of nitrogen (anhydrous ammonia) was applied to the soil. An additional 250kg/ha of nitrogen was applied in the irrigation water when the plants were 1m tall. Supplemental irrigation water was applied based on soil tensionmeter reading at the 46.3cm level during the critical period of 10 days prior to anthesis to about 45 days into grain-fill. The HYE2 was located at the Herman Warsaw's farm, Saybrook, Illinois. The soil type of this field is a Saybrook fine silty-loam (mesic Typic Argiudolls). Maize was grown in a plot with two 5.8m rows and plant density of 83,708 plants/ha. Maize was planted on 29 April, 1985. The fall application of fertilizer has included 280kg/ha of phosphorus and potassium. Prior to planting 280kg/ha of nitrogen was applied to the soil and an additional 280kg/ha of nitrogen was sidedressed when plants were 1m tall. The UNE1 was located at the Agronomy-Plant Pathology Farm of University of Illinois at Urbana, Illinois. The soil type of this field is a Drummer fine silty clay-loam (mesic Typic Haplaquolls). Maize was planted on 26 April, 1985 and grown in plots consisting of a single 5.3m row with plant density of 61,508 plants/ha. Fertilizer applications consisted of 241kg/ha of nitrogen at planting and a fall application of 207kg/ha of phosphorus and potassium. The UNE2 was located at the Agronomy-Plant Pathology Farm of University of Illinois at Urban, Illinois. The soil type of this field is a Flanagan fine silty-loam (montmorillonitic mesic Aquic Argiudolls). Maize was planted on 7 May, 1985. The row length, row spacing, plant density and fertilizer application in UNE2 were the same as in UNE1.

All yield trials were machine-planted. All plots were overplanted and thinned to a perfect stand. Prior to harvest, the number of stalk lodged plants (plants broken below

the ear-node) in each plot were determined. Using these data percent stalk lodging was calculated for all plots. The HYE1 was hand-harvested while HYE2, UNE1 and UNE2 were machine-harvested. Individual plot grain weight and grain moisture was determined and the grain yield calculated as megagrams per hectare (Mg/ha) at 15.5% moisture level.

Plant height, ear height and penetrometer measurements were determined only for the HYE1 and UNE1 experiments. Plant height and ear height were measured after anthesis, on five plants per plot by measuring the distance (cm) from the soil surface to the flag leaf collar and soil surface to the ear-bearing node, respectively. Approximately three weeks after anthesis, rind puncture measurements (Kg) were taken on five plants in a plot using a commercially available (Chatillon) hand-held penetrometer. Penetrometer measurements were taken in the center of the second elongated internode above ground. The means of these measurements were calculated for each plot. The total number of ears (ears with more than 50% seed set) were counted and divided by the number of plants harvested in each plot to calculate ear number per 100-plants.

In HYE1 a 250g grain sample was saved from each plot. The total kernel number in each 250g sample was counted and weight per kernel (g) was calculated. The kernel number per ear was obtained by: (Grain yield per plot (g)/Weight per kernel (g))/Number of ears per plot. The 300-kernel weight (g) at 15.5% moisture content was obtained by:  $(300 \times \text{Weight per kernel}) \times (1 - \text{Moisture content}) / .845$ .

Evaluation of progress for multiple disease resistance was conducted in disease nursery. Single-row plots 3.8×0.76m were overplanted and thinned to 9 plants/plot (30, 999 plants/ha). All plants were inoculated twice (June 12th and June 30th), by dropping into the whorl ground leaf tissue collected the previous fall from plants heavily infected with multiple leaf disease (*Exserochilum turcicum*, *Bipolaris maydis*, and *Colletotrichum graminicola*). In each plot 5 plants were inoculated with a mixture of stalk rotting organisms (*Diplodia maydis*, *Gibberella zeae*, *Fusarium moniliforme*, and *Colletotrichum graminicola*) by injecting a conidia suspension ( $1 \times 10^5$  conidia/ml) into the first elongated internode above the soil approximately 2 weeks after silking. After flowering, the multiple leaf disease reaction was rated (in % leaf area infected on a plot basis) 3 times with 2 week intervals between ratings. At physiological maturity multiple stalk-rot inoculated plants were cut off below the ear and split longitudinally to ground level. Multiple stalk-rot reaction was recorded on a 1 to 9 scale: 1=no spread or less than 50% of discolored tissue in the inoculated internode; 2=more than 50% of discolored tissue in the inoculated internode; 3=discolored tissue reaches lower half of 2nd internode; 4=discolored tissue reaches upper half of the 2nd internode; 5=discolored tissue reaches lower half of the 3rd internode; 6=discolored tissue reaches upper half of the 3rd internode; 7=discolored tissue reaches lower half of the 4th internode; 8=discolored tissue reaches upper half of the 4th internode; 9=discolored tissue reaches the 5th internode or plant prematurely killed.

#### Field Design And Statistical Analysis

A split plot experiment with the main plots arranged in a randomized complete block

design with four replicates was used for all experiments in this study. Populations, population cross and populations $\times$ testers were main plots and cycles of selection were subplots. The analyses of variance was used for all traits, using plot mean data in each experiment. The total sum of squares were partitioned into components for blocks, populations, error a, cycles, populations $\times$ cycles and error b. Combined analyses for environments were calculated using methods suggested by McIntosh<sup>(22)</sup>. In the combined analyses for environments, the total sums of squares were partitioned into environments, blocks/environments, populations, environments $\times$ populations, error a, cycles, environments $\times$ cycles, populations $\times$ cycles, environments $\times$ populations $\times$ cycles, and error b. F-tests, populations and cycles were considered fixed, and environments random. All components of the analyses of variance were tested against their appropriate error term or interactions.

For each analysis of variance above, regression analysis was used within each population. The total sum of squares for cycles were partitioned into sum of squares for linear, quadratic and cubic regression. Since linear regression explained most of the variability among cycles of selection, only linear regression coefficients are presented and used to measure rate of change per cycle. Standard errors were calculated for the regression coefficients using the method described by Steel and Torrie<sup>(31)</sup>. In comparing estimates of linear regression coefficients, the values with confidence intervals that do not overlap are considered to be significantly different from each other at the 5% level of probability.

## RESULTS AND DISCUSSION

The two populations used in this study had similar grain yield potential but RSSSC had better stalk quality than BS10. The four environments represented highly productive Illinois corn growing environments. The HYE1 represented a very good management level for corn, with very high fertility, irrigation and high plant density. Grain yield in HYE1 was very high and consistent. The HYE2 represented a corn field with very high fertility and high plant density. Stalk lodging usually caused some grain yield reduction in HYE2. The UNE1 represented a corn field with high fertility and normal plant density. Grain yield in UNE1 was higher than average over the normal environments. The UNE2 represented a corn environment with normal fertility and normal plant density. However, none of the linear regression coefficients within population among environments was significantly different from each other.

The combined data showed 0.95, 0.69, 0.65, 0.65 and 0.24 Mg/ha/cycle significant increases of grain yield over 3 cycles for BS10, RSSSC, BS10 $\times$ RSSSC, BS10 $\times$ B37 and RSSSC $\times$ B79, respectively (Table 1). The smaller grain yield response observed in RSSSC $\times$ B79 in this study was not expected. Since selection cycle means among C<sub>0</sub>-C<sub>3</sub> were similar for RSSSC $\times$ B79, it is suspected that inbred tester B79 may have some masking effect on the RSSSC $\times$ B79 progenies performance. Similar masking effect of inbred tester on testcross progenies performance has been reported by Walejko and Russell<sup>(36)</sup>. They used B73 as inbred tester and crossed with Lancaster C<sub>0</sub> and C<sub>3</sub> and with Kolk-

**Table 1.** Means and linear regression coefficients ( $b_1$ ) for grain yield and stalk lodging of BS10 and RSSSC populations, improved by three cycles of reciprocal recurrent selection in a high-yield environment, and evaluated at two environments, Illinois, 1985.

Population	Grain yield (Mg ha <sup>-1</sup> )	Stalk lodging (%)
BS10-C <sub>0</sub>	8.22	46.2
BS10-C <sub>1</sub>	9.21	36.3
BS10-C <sub>2</sub>	10.25	24.3
BS10-C <sub>3</sub>	11.06	20.3
$b_1^+$	0.95 ± 0.11	-9.0 ± 0.71
RSSSC-C <sub>0</sub>	9.00	28.9
RSSSC-C <sub>1</sub>	9.78	24.5
RSSSC-C <sub>2</sub>	10.42	26.3
RSSSC-C <sub>3</sub>	11.08	28.7
$b_1$	0.69 ± 0.11	0.1 ± 0.71
BS10-C <sub>0</sub> × RSSSC-C <sub>0</sub>	9.94	34.6
BS10-C <sub>1</sub> × RSSSC-C <sub>1</sub>	10.98	28.0
BS10-C <sub>2</sub> × RSSSC-C <sub>2</sub>	11.37	23.6
BS10-C <sub>3</sub> × RSSSC-C <sub>3</sub>	11.97	18.2
$b_1$	0.65 ± 0.11	-5.4 ± 0.71
BS10-C <sub>0</sub> × B37	10.45	14.0
BS10-C <sub>1</sub> × B37	11.80	11.5
BS10-C <sub>2</sub> × B37	11.83	6.6
BS10-C <sub>3</sub> × B37	12.61	4.0
$b_1$	0.65 ± 0.11	-3.5 ± 0.71
RSSSC-C <sub>0</sub> × 79	11.37	18.9
RSSSC-C <sub>1</sub> × 79	11.51	19.1
RSSSC-C <sub>2</sub> × 79	11.11	20.0
RSSSC-C <sub>3</sub> × 79	12.30	19.5
$b_1$	0.24 ± 0.11	-0.3 ± 0.71

<sup>+</sup> $b_1$  values greater than twice standard error are considered significantly different from zero.

meier C<sub>0</sub> and C<sub>5</sub>. In both cases no significant differences between C<sub>0</sub> and C<sub>5</sub> testcrosses could be detected. They concluded B73 has a relatively high frequency of favorable, dominant alleles that 'masked' the effects of the less favorable, recessive alleles in the two populations. However, gene frequencies in heterogeneous population may vary from 0 to 1.0 and include multiple alleles at many loci. Theoretically, the tester parent should contribute 50% of the genes to the testcrosses. In addition, to this dilution effect, genes from the tester may be dominant, epistatic, or complementary, with genes

from the  $S_1$  genotypes to be evaluated. If genetic interactions occur, differences in phenotypic performances of the testcrosses may not be easy to distinguish. The less accurately genotypes are evaluated, the more random selection becomes.

Plants grown under high plant densities (HYE1 and HYE2) usually have more stalk lodging than plants grown in normal plant densities (UNE1, UNE 2). Comparing between HYE1 and HYE2, and between UNE1 and UNE2 indicated stalk lodging resistance can be improved by selection in a HYE. Combined data from three cycles of selection indicates significant response for stalk lodging were observed in BS10 ( $b_1 = -9.0\%$ ), BS10×RSSSC ( $b_1 = -5.4\%$ ) and BS10×B37 ( $b_1 = -3.5\%$ ). RSSSC and RSSSC×B79 showed nonsignificant response to selection in all four environments.

Goulas and Lonquist<sup>(7)</sup> suggested that the HS- $S_1$  evaluation may lead to selections with better buffering against environment changes. In this study for both grain yield and stalk lodging the responses were similar among environment, supporting this concept. Most studies reported a positive relationship between grain yield and stalk lodging<sup>(32,34,35)</sup>. However, no significant relationship between grain yield and stalk lodging have also been reported<sup>(28)</sup>. Our data indicate a simultaneous improvement of grain yield and stalk lodging resistance in BS10 population *per se* and population crosses. This agrees well with results of Colbert *et al.*<sup>(2)</sup> and Eberhart *et al.*<sup>(4)</sup>.

Plants grown in higher plant density (HYE1) usually had higher plant height and ear height. In this study HYE1 and UNE1 had similar plant height and ear height. The trends of the mean values over cycles for plant height were similar to the trends for ear height (Table 2). The selection response for HYE1 and UNE1 were about the same. Combined data showed that RSSSC, BS10×RSSSC and RSSSC×B79 significantly increased in plant height of 9.2, 3.8 and 3.2cm/cycle, and significantly increased in ear height of 7.0, 4.1 and 5.1 cm/cycle, respectively. Nonsignificant changes of plant height and ear height to selection for BS10 and BS10×B37 were observed (Table 2). Penetrometer reading was slightly higher for RSSSC than BS10. After three cycles of selection all populations showed a significant increase in rind penetrometer reading. Combined data showed that significant gains per cycle were 0.30, 0.47, 0.36, 0.33 and 0.16 kg for BS10, RSSSC, BS10×RSSSC, BS10×B37 and RSSSC×B79, respectively.

Compared to population BS10, population RSSSC had relatively less progress in stalk lodging. Population RSSSC had better stalk quality in the original population than BS10. The increase in plant height and ear height in advanced cycles of RSSSC may have caused the lack of a decrease in stalk lodging. However, for a more rapid improvement in reduction of stalk lodging of RSSSC selection for reducing plant height and ear height or using penetrometer reading as supplemental methods when under taking a population improvement program for grain yield and multiple disease resistance may be useful.

Three cycles of selection resulted in a significant change in ear number/100-plants in BS10 ( $b_1 = -5.9$ ) and RSSSC×B79 ( $b_1 = 2.4$ ). The two populations showed a significant increase in 300-kernel weight, BS10 and RSSSC had a 4.3 and 4.8 g/cycle significant increase, respectively. Population crosses and populations×testers showed nonsignificant

**Table 2.** Means and linear regression coefficients ( $b_1$ ) for plant height, ear height and penetrometer reading of BS10 and RSSSC populations improved by three cycles of reciprocal recurrent selection in a high-yield environment, and measured at two environments, Illinois, 1935.

Population	Plant height (cm)	Ear height (cm)	Penetrometer reading (kg)
BS10-C <sub>0</sub>	234.9	128.5	7.31
BS10-C <sub>1</sub>	235.1	132.6	7.46
BS10-C <sub>2</sub>	239.0	130.5	7.76
BS10-C <sub>3</sub>	238.9	129.7	8.21
$b_1^+$	1.6± 0.94	0.2± 1.33	0.30± 0.07
RSSSC-C <sub>0</sub>	235.6	122.6	7.09
RSSSC-C <sub>1</sub>	246.9	127.9	7.85
RSSSC-C <sub>2</sub>	248.6	134.0	7.96
RSSSC-C <sub>3</sub>	265.6	144.0	8.61
$b_1$	9.2± 0.94	7.0± 1.33	0.47± 0.07
BS10-C <sub>0</sub> ×RSSSC-C <sub>0</sub>	235.2	124.9	7.17
BS10-C <sub>1</sub> ×RSSSC-C <sub>1</sub>	240.3	126.6	7.76
BS10-C <sub>2</sub> ×RSSSC-C <sub>2</sub>	243.8	127.7	7.88
BS10-C <sub>3</sub> ×RSSSC-C <sub>3</sub>	246.8	138.3	8.34
$b_1$	3.8± 0.94	4.1± 1.33	0.36± 0.07
BS10-C <sub>0</sub> ×B37	240.2	127.5	7.63
BS10-C <sub>1</sub> ×B37	236.7	124.0	7.77
BS10-C <sub>2</sub> ×B37	241.3	126.8	8.15
BS10-C <sub>3</sub> ×B37	241.9	123.4	8.61
$b_1$	1.0± 0.94	-0.9± 1.33	0.33± 0.07
RSSSC-C <sub>0</sub> ×B79	234.5	127.0	7.73
RSSSC-C <sub>1</sub> ×B79	235.4	133.0	8.13
RSSSC-C <sub>2</sub> ×B79	234.9	133.5	7.92
RSSSC-C <sub>3</sub> ×B79	245.4	143.6	8.34
$b_1$	3.2± 0.94	5.1± 1.33	0.16± 0.07

<sup>+</sup> $b_1$  values greater than twice standard error are considered significantly different from zero.

response to selection in 300-kernel weight. The BS10 also had significantly increased kernel number/ear ( $b_1=23.5$ ). Changes of grain moisture from selection were only observed in BS10 ( $b_1=0.5\%$ ) and BS10×B37 ( $b_1=0.4\%$ ). After three cycles of selection grain yield improvement in BS10 was mainly due to increase in both 300-kernel weight and kernel number/ear, while in RSSSC the yield increase was mainly due to increase in 300-kernel weight (Table 3).

Multiple leaf disease resistance and multiple stalk-rot resistance were improved in

**Table 3.** Means and linear regression coefficients for ear number/100-plants, 300-kernel weight, kernel number/ear, and grain moisture of BS10 and RSSSC populations improved by three cycles of reciprocal recurrent selection in a high-yield environment, and measured at HYE, Illinois, 1985.

Population	Ear number/100 plants	300-Kernel weight (g)	Kernel number/ear	Grainmoisture (%)
BS10-C <sub>0</sub>	126.3	99.1	317.8	18.8
BS10-C <sub>1</sub>	115.1	100.1	337.3	19.2
BS10-C <sub>2</sub>	112.6	107.3	347.4	20.0
BS10-C <sub>3</sub>	107.4	111.1	392.8	20.3
b <sub>1</sub> <sup>+</sup>	-5.9± 1.15	4.3± 1.33	23.5± 7.17	0.5± 0.16
RSSSC-C <sub>0</sub>	102.6	98.6	394.5	19.8
RSSSC-C <sub>1</sub>	103.3	100.0	385.1	19.6
RSSSC-C <sub>2</sub>	104.0	108.6	394.9	19.6
RSSSC-C <sub>3</sub>	102.7	111.8	397.6	20.6
b <sub>1</sub>	0.1± 1.15	4.8± 1.33	1.9± 7.17	0.2± 0.16
BS10-C <sub>0</sub> ×RSSSC-C <sub>0</sub>	104.6	108.9	386.6	19.2
BS10-C <sub>1</sub> ×RSSSC-C <sub>1</sub>	107.4	110.8	408.3	19.4
BS10-C <sub>2</sub> ×RSSSC-C <sub>2</sub>	104.9	112.1	419.9	19.2
BS10-C <sub>3</sub> ×RSSSC-C <sub>3</sub>	107.9	114.4	399.5	20.3
b <sub>1</sub>	0.7± 1.15	1.8± 1.33	5.0± 7.17	0.3± 0.16
BS10-C <sub>0</sub> ×B37	106.6	104.5	387.0	19.7
BS10-C <sub>1</sub> ×B37	100.7	108.9	401.6	19.9
BS10-C <sub>2</sub> ×B37	100.0	109.9	402.1	19.9
BS10-C <sub>3</sub> ×B37	102.0	110.5	418.1	21.0
b <sub>1</sub>	-1.5± 1.15	1.9± 1.33	9.4± 7.17	0.4± 0.16
RSSSC-C <sub>0</sub> ×B79	107.3	109.4	422.4	21.0
RSSSC-C <sub>1</sub> ×B79	108.9	106.0	426.8	20.5
RSSSC-C <sub>2</sub> ×B79	109.4	104.6	410.1	20.7
RSSSC-C <sub>3</sub> ×B79	115.1	110.9	418.0	20.8
b <sub>1</sub>	2.4± 1.15	0.3± 1.33	-3.0± 7.17	-0.1± 0.16

<sup>+</sup>b<sub>1</sub> values greater than twice standard error are considered significantly different from zero.

populations *per se* and population crosses (Table 4). Selection responses were similar among populations and population crosses. Means of three ratings showed that BS10, RSSSC and BS10×RSSSC had a 4.3, 4.5 and 4.5%/cycle significant decrease in percent leaf area infected, respectively. After three cycles of selection BS10, RSSSC and BS10×RSSSC had a 1.1, 0.7 and 1.2 unit/cycle decrease in multiple stalk-rot rating (scale 1 resistant—9 susceptible), respectively. Several researchers have shown that recurrent selection was effective in improving resistance to corn leaf blight<sup>(12,23,24)</sup> and Stalk-rot

**Table 4.** Means and linear regression coefficients ( $b_1$ ) for multiple leaf disease and multiple stalk rot ratings of BS10 and RSSSC populations improved by three cycles of reciprocal recurrent selection, and evaluated in disease nursery, Urbana, Illinois, 1985.

Population	Multiple leaf disease (% leaf area infected)	Multiple stalk rot (1-9 scale)
BS10-C <sub>0</sub>	44.8	8.1
BS10-C <sub>1</sub>	37.9	7.4
BS10-C <sub>2</sub>	36.1	6.4
BS10-C <sub>3</sub>	31.0	4.7
$b_1^+$	$-4.3 \pm 0.52$	$-1.1 \pm 0.26$
RSSSC-C <sub>0</sub>	51.3	8.6
RSSSC-C <sub>1</sub>	47.3	7.5
RSSSC-C <sub>2</sub>	43.4	7.2
RSSSC-C <sub>3</sub>	37.7	6.2
$b_1$	$-4.5 \pm 0.52$	$-0.7 \pm 0.26$
BS10-C <sub>0</sub> × RSSSC-C <sub>0</sub>	44.2	8.4
BS10-C <sub>1</sub> × RSSSC-C <sub>1</sub>	40.4	6.9
BS10-C <sub>2</sub> × RSSSC-C <sub>2</sub>	34.2	6.1
BS10-C <sub>3</sub> × RSSSC-C <sub>3</sub>	31.3	4.7
$b_1$	$-4.5 \pm 0.52$	$-1.2 \pm 0.26$

<sup>+</sup> $b_1$  values greater than 2.052 standard error are considered significantly different from zero.

(13,20,23,24,30). Our data indicate that three cycles of phenotypic mass selection largely increased multiple leaf disease and multiple stalk-rot resistance for populations *per se* and population crosses. This agrees well with results from other works.

Reported results from use of recurrent selection usually have been positive. Response to grain yield in intrapopulation improvement has been approximately 2 to 4% per cycle of selection<sup>(9)</sup>. Direct response to reciprocal recurrent selection has varied from 3.1% per cycle for BSSS × BSCB1 in Iowa to 6% for "Teko Yellow Horsetooth" and "Natal Yellow" in South Africa and 7% for "Kitals Synthetic II" and "Ecuador 573" in Kenya, East Africa. Indirect response to selection for the base populations *per se* varied from 0 to 7% per cycle<sup>(3,11,25,27,29)</sup>. Direct responses to reciprocal full-sib selection in the population cross was 2.1%<sup>(10)</sup>. Correlated response in BS10 and BS11 was 2.7 and 2.4%, respectively. Despite of different selection intensities and different cycles of selection used in different breeding programs, a gain of 11.5, 7.7 and 6.8% per cycle for grain yield obtained in this study for BS10, RSSSC and BS10 × RSSSC, respectively, compare favorably with published reports.

Gain from three cycles of reciprocal recurrent selection was satisfactory in the populations *per se*, population crosses and populations × testers for grain yield, multiple leaf disease resistance and multiple stalk-rot resistance. Stalk lodging resistance was

improved in population BS10 and population crosses. Correlated changes in other agronomic traits were mostly desirable. The result suggests that the procedures of HYE selection are beneficial in developing maize population *per se* and hybrids with high grain yield, multiple leaf disease resistance, multiple stalk-rot resistance and good stalk quality.

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# 玉米族羣相互輪迴選拔之選種效應評估<sup>1</sup>

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## 摘 要

在高產環境下，利用 BS10及RSSSC 兩個玉米族羣進行兼顧族羣內及族羣間改良之相互輪迴選拔。族羣內之改良包括多種葉斑病、莖腐病等抗病性的外表型混合選種及S<sub>i</sub>系統在高產環境下之產量評估。族羣間之改良則包括測交系統在高產環境下之產量試驗及選拔。三個輪迴之選種效應評估，分別利用族羣、族羣雜種及族羣測交種等，於四個不同環境下進行產量試驗；並利用族羣及族羣雜種於病圃檢定其對葉斑病及莖腐病之抵抗力。試驗結果摘要如下：

- (1) 選拔效應不因評估環境之不同而有明顯差異。
- (2) 族羣本身、族羣雜種以及族羣測交種之子實產量、多種葉病與莖腐病之抵抗力等之改良效果頗為顯著。在子實產量方面，BS10, RSSSC, BS10×RSSSC, BS10×B37, 及 RSSSC×B79分別達到0.95、0.69、0.65、0.65及0.24噸／公頃／輪迴之增進效果。在抗倒伏性方面，BS10, BS10×RSSSC及BS10×B37分別為-9.0、-5.4及-3.5％／輪迴之選種效應。所有族羣、族羣雜種及族羣測交種之Penetrometer reading亦顯著地增強。
- (3) 就本研究之育種目標而言，相關性狀之改變，以合意者居多。其中較為不利之變化為RSSSC, BS10×RSSSC及RSSSC×B79等之株高及穗位高之增加，及BS10每株穗數之減少。有利的部分則包括BS10之300粒重及每穗粒數，及RSSSC 300粒重之增加等。
- (4) 本試驗結果顯示：高產環境下進行相互輪迴選拔，對改良玉米子實產量、病害抵抗力及抗倒伏性成效顯著，為一有利的選拔方式。

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