MAIZE *(Zea mays L.)* GENETIC ADVANCES THROUGH S_1 RECURRENT SELECTION IN ETHIOPIA

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ABSTRACT

This paper presented the genetic gain and progress made in improving grain yield, plant height, ear placement, resistance to lodging and other desirable agronomic traits in Ukuruguru Composite B (UCB) maize variety through two cycles of selection. Three hundred and sixty and two hundred and fifty-four S_1 families were evaluated in three environments and 36 and 25 families were selected following 10% selection intensity during the first (C_1) and the second (C_2) cycles, respectively. The progress made through selection was determined by evaluating the parent population (UCB C_0), the first and the second selection cycles in six environments in a randomized complete block design with four replications. Commercial open pollinated and hybrid varieties were included as checks. UCB S_1 C_2 produced mean grain yield and had a significant genetic gain with mean gain. It was concluded that two cycles of S_1 recurrent selection have brought significant genetic improvement in grain yield and major agronomic traits in UCB. Hence UCB S_1C_2 was fully released and recommended for commercial production in the mid altitude (1600-1800 masl) agro ecologies of Jimma and Illubabore zones, in South Western part of Ethiopia.

Keywords: *Genetic gain, morka, recurrent selection, response to selection, Ukuruguru Composite B*

INTRODUCTION

The late maturing composites of east African origin are well adapted to the potential maize environment in Ethiopia. Originally introduced from Tanzania, Ukuruguru Composite B (UCB) used to be the most adapted and well preferred variety in Jimma and Illubabore zones in the southwestern part of the country since its release in 1975. The variety was reported to possess adequate level of resistance to the major leaf diseases, such as turcicum leaf blight (TLB) (Helminthosporium turcicum), common rust (CR) (Puccinia sorghi) (Assefa, 1995) and also to the recently introduced gray leaf spot (GLS) (Cercospora zeae-maydis) (Dagne et al., 2001) and storage pests (Demissew et al., 2004).

It, however, grows tall and reaches a height of 350cm with heavy cobs placed at 250cm almost three quarters up the plant. As a result it is susceptible to lodging and gives high yield only when there is no heavy wind accompanying rain storm. Therefore a considerable amount of grain yield is lost, especially in a hot and humid climate where germination and rotting are easily initiated. Other than this, leafiness and inefficient transfer of assimilates to ear sink are also considered to be important limitations to grain yield in most of locally adapted east African composites and in UCB in particular (Benti, 1986; Benti et al., 1988).

Accumulation of undesirable traits through cross pollination with pollen from nearby maize fields has worsen the situation by accelerating genetic deterioration of the variety leading to low yield potential. Despite its resistance to biotic constraints, it was, therefore, no more attractive to grow the variety with all the limitations. Farmers have, therefore, withdrawn from growing the variety and seed production was stopped in 1995. To solve this problem, the maize breeding team based at Jimma Agricultural Research Center (JARC) has been working on improving the variety through S1 recurrent selection since 1998.

In maize several studies indicated that the inheritance of ear height is controlled by additive genes (Robinson et al., 1949, Giesbrecht, 1961 and Harville et al., 1978). Similar studies carried out in Ethiopia in locally adapted maize composites of east African origin have also confirmed that the inheritance of grain yield and, ear and plant height is mainly controlled by additive gene effects (Leta and Ramachandrappa, 1998 and Jemal, 1999) implying that selection programmes that utilize additive gene effects can be useful in improving these quantitative characters.

Initially tested by East and Jones (1918) and Hayes and Garber (1919) to improve quantitative traits in allogamous crops, recurrent selection is extensively used in maize breeding (Hallauer, 1985). Recurrent selection methods for intrapopulation improvement of quantitative characters in maize have been based on individual or family performance for improvement of the population per se or hybrid-testcross family or for improvement of combining ability of the population (Hallauer and Miranda, 1981). Among those selection methods, S_1 recurrent selection has been effective in improving grain yield and other traits in cross pollinated crops. In maize it is considered to be more efficient than other selection schemes in improving a broad based population.

Burton et al. (1971) realized gains of 4.2% cycle-1 over four cycles of selection for grain yield in Krug. Genter (1973) found that S1 recurrent selection was more effective than top-cross selection for improving population per se performance and was equal to test cross selection for improving combining ability. Besides its effectiveness in improving performance in terms of productivity, it has been useful in improving resistance to biotic stresses such as European corn borer (Penny et al., 1967), stalk rote (Jinahyon and Russell, 1969) and downy mildew (De Leon et al., 1993). In Ethiopia, various forms of intra and interpopulation recurrent selection schemes have been practiced to improve different populations. Full sib family and mass selection have resulted in improving varieties for higher grain yield, and lodging and disease resistance (Benti et al., 1993). The improved versions were either used as sources of inbred lines in hybrid development program or released as improved varieties for commercial production. In this improvement program, S1 recurrent selection has been carried out in UCB to improve grain yield, plant height and ear placement, resistance to lodging and other desirable agronomic traits. This paper presents the genetic gain and progress made in improving these traits through two cycles of selection.

MATERIALS AND METHODS

Two cycles of S_1 recurrent selection have been carried out in UCB. Each cycle involved family generation, evaluation and recombination. After two cycles of selection, the selection cycles were evaluated in multilocation field experiments to find out genetic gains and progress achieved through the improvement program. The details of the protocols are elaborated below.

Family generation: To generate S1 families in both the first and the second cycles the parent population, UCB C_0 , and the half sib recombined generation of the first cycle, UCB S_1 C_1 F_1, were planted in a uniform and large plot at Jimma Agricultural Research Center. In both cases, recommended management practices and fertilizer levels were applied except row and plant spacing which were set at 80 and 50 cm, respectively, to enable plants sufficiently express their genetic potential for better success in selecting ideal types.

The first cycle was initiated by selfing 500 plants selected based on plant and ear height and resistance to diseases. Ears of the selected plants were covered by polytine plastics before silk emergence and kept under close supervision until pollination. All the candidate plants were regularly visited for silk emergence and pollen shading. Depending on the synchrony of silk emergence and pollen shading, the tassels of the selected plants were covered by pollen bag a day before pollination. Then pollen was collected on subsequent days and all the covered silks were self pollinated. Ears suspected to have been open pollinated were rejected.

The pollen bags were kept on the pollinated ears until harvest. Selfed plants observed to be severely attacked by leaf diseases and/or root or stalk lodged at advanced development stages were eliminated. Selfed ears were harvested individually and further selection was finally exercised based on ear characters and rotting. The second cycle was initiated by selfing 350 selected plants in the first half sib recombined generation, UCB S_1 C_1 F_1, of the first cycle of selection. Plants were selected and self pollinated and then best ears selected following the same procedures mentioned above. Finally 360 and 254 selfed ears were shelled individually as S1 families and put in family evaluation in the first and second cycles, respectively.

Family evaluation: In order to select families which have desirable traits, the 360 and 254 families generated in the first and second cycle were evaluated in a 19 x 19 and 16 x 16 (0, 1) alpha lattice design with two replications in the main season of the year 2000 and 2002, respectively, at Jimma Agricultural Research Center (JARC), Hurumu Testing Site (HTS) and Bako Agricultural Research Center (BARC) in the western and southwestern part of Ethiopia. Two rows each of 5.1 meter length were grown per plot with spacing of 75 and 30 cm between the rows and plants, respectively.

Two seeds were planted hill^{-1} and then thinned to one plant hill^{-1} to adjust the plant density to 44,444 plants hectare^{-1}. UCB C_0, and UCB C_0 and UCB S_1 C_1 F_1 were included in the first and second experiments, respectively, as reference entries in selecting the best families. The number of families evaluated in the first cycle was reasonably high to increase the chances of capturing families with low ear placement and short plant height. In both cycles, selection intensity of 10% was followed to select the best families based on the mean data combined across the three locations and visual selection in the field. Accordingly, 36 and 25 best families were selected for recombination to compose the first and the second selection cycles, respectively.

Family recombination: The selected families were recombined in isolated half-sib recombination block using remnant seeds. The families were planted in separate rows and served as female rows by detasseling before pollen shading. A balanced composite of seed was mixed from all the selected families and planted as male rows in between the female rows. The seed harvested from the female rows were mixed and planted in isolation for further recombination. The first and the second cycles were further recombined in isolation up to the third and the second generation, respectively, before promoting to multilocation field experiments.

Evaluation for progress through selection: To determine the progress made through selection, the parent population (UCB C_0), and the first (UCB S_1 C_1) and the second (UCB S_1 C_2) selection cycles were evaluated in field experiments in Ethiopia at Jimma Agricultural Research Center (JARC), Bako Agricultural Research Center (BARC) and Hurumu Testing Site (HTS) in 2005, Bako Agricultural Research Center (BARC) and Hurumu Testing Site (HTS) in 2006 and at Bako Agricultural Research Center (BARC) in 2007. Totally in a six year-location environment, entries were arranged in a randomized complete block design with four replications at each environment. Four rows each of 5.1 meter length were grown in a plot with spacing of 75 and 30 cm between the rows and plants, respectively. Two seeds were planted hill^{-1} and then thinned to one plant hill^{-1} to adjust the plant density to 44,444 plants hectare^{-1}. All management practices and fertilizer levels were applied following specific research recommendations for each location. Commercial open pollinated (OPVs) and hybrid varieties were included as checks.

Data on grain yield and all agronomic characters were recorded on the two middle rows. Plant and ear height were measured on ten randomly selected plants and the mean was recorded for the plot. Ear position was calculated as the ratio of ear height to plant height. All plots were hand harvested and field weight of the harvested cobs was measured. Grain yield was then computed considering 80% shelling per cent and adjusted at 12.5% moisture. Data on disease severity were recorded in a 1-5 scale, where 1 indicates clean or no infection and 5 severely diseased, and then log transformed before analysis. Analysis of variance was done separately for each environment and then combined across environments using MSTAT-C software.

The data from the experiment conducted at Bako in 2005 was excluded from the combined analysis because of high error variance for all variables. Genetic gains $cycle^{-1}$ were calculated as $[(C_n - C_{n-1})/C_{n-1}]$ 100, where n is the number of cycle. The overall response to selection (R) as a change in population mean was calculated by subtracting the average of the second cycle from the average of the whole population before selection. As a measure of the selection applied, selection differential (S), was estimated as a deviation of the mean phenotypic value of the individual families selected as parents for recombination from the mean phenotypic value of the parental population before selection (UCB C_0 in the first cycle and UCB C_2 F_2 in the second cycle). In order to show how the response is related to the selection differential, realized heritability (h^2r) was estimated as $h2r = {}^R/_S$, as indicated by Falconer (1989).

RESULTS AND DISCUSSION

Combined analysis of variance for grain yield, days to 50% silking, ear and plant height, ear position, and severity of gray leaf spot (GLS), turcicum leaf blight (TLB) and common rust (CR) indicated highly significant differences among the varieties (Table 1). Mean squares due to genotype X environment (G X E) interaction was also significant for all characters except plant height and ear position. No significant differences were observed among varieties for lodging per cent. Therefore response to selection was not measured for lodging per cent. Mean grain yield combined across five environments varied from 5.7 to 8.7 t ha^{-1} (Table 2). The second selection cycle (UCB S_1 C_2) produced the highest mean grain yield and had a significant ($P<0.01$) genetic gain of 30% (2.0t ha^{-1}) (Table 3). Cycle wise, the gains were 0.8 (11.0%) and 1.2t ha^{-1} (16.4%) in the first and second cycles, respectively, indicating progressive increases in productivity with cycles of selection. The mean genetic gain for grain yield $cycle^{-1}$ was 15.0% (1.0t ha^{-1}). This is immense compared with 44% yield increase reported by Janet and West (1993) after four cycles of S1 selection exercised in a population that has undergone 10 cycles of mass selection for low ear height.

UCB S_1 C_2 was also improved for short plant height, low ear placement and ear position. Plant height was reduced significantly ($P<0.01$) with genetic gain of 9.6% (30.8cm). The regresses with cycles were 4.1% (13.3cm) in the first and 5.6% (17.5cm) in the second cycle with mean reduction of 4.92 % (15.4cm) cycle^{-1}. Ear height was also reduced significantly and followed similar trend with plant height but with more magnitude. It decreased by 20% (39.7cm) from 201.7cm in the parent population to 162 cm in the second cycle. The mean reduction cycle^{-1} was 10.4% (19.8cm) with statistically significant ($P< 0.01$) drops of 9.5% (19.2cm) and 11.2% (20.4cm) in the first and second cycle, respectively. Both traits diminished progressively with cycles of selection.

To demonstrate more clearly, changes of those traits with cycles of selection, linear regression lines were fitted to the mean values of grain yield and other agronomic traits (Fig 1 a & b), in the parent population and the two selection cycles plotted against cycles of selection. It is very clear to see the slopes of the regression equations indicating the average realized gains in selection for those traits cycle^{-1} of selection. If we take the slopes of these equations and express them as per cent of the mean values recorded in the parent population for a particular trait they give the average gains cycle^{-1} in per cent which is the same as the gains cycle^{-1} computed using the previous formulae. For instance, expressing the slope of the regression line fitted to grain yield which is unity as a per cent of the mean grain yield of the parent population gives us 14.6 per cent as mean gain in grain yield cycle^{-1}. Contrary to grain yield, the slopes of the regression lines fitted to ear and plant height are negative substantiating reduction of these traits with cycles of selection. Expressing these values as per cent of the mean ear and plant height of the parent population, yields mean responses of -10.3 and -5.0 per cent cycle^{-1}.

Considering positive genetic correlation of grain yield with ear and plant height in maize (Miranda and Hallauer, 1981) the negative response observed in ear and plant height in association with positive response in grain yield was quite interesting. This might have happened since low ear placement and short plant height, and better grain yield were set as selection criteria in this improvement program. Other selection experiments in which grain yield was the only selection criterion have produced variable effects on ear height as a correlated response. Harris et al. (1972); Moll et al. (1975) reported increases in ear height when grain yield was the only selection criterion. On the other hand, Walejko and Russell (1977); Crosbie and Mock (1980) reported no significant changes in ear height following selection for grain yield.

In addition to responses to selection, it was also important to measure selection differential since it is the relationship between the two, and not the responses alone, that is of interest from the genetic point of view (Falconer, 1989). Selection differential was computed as the deviation of the mean of the families selected for recombination in each cycle from the mean of the respective parent populations with the assumption that all the selected families were equally fertile in setting seeds and shading fertile pollen and have equally contributed to the subsequent selection cycles. As a quotient of the two parameters, realized heritability is an index used to quantify the degree to which a trait in the population can be changed through selection. Higher values indicate better position of the selection cycle than the original population, hence indicating the rate at which the population is changing in a particular trait. In this study realized heritability was found to increase progressively with the selection cycles for the major agronomic traits indicating better response of the population to selection (Table 4). For grain yield realized heritability was 0.44 and 0.84 in the first and second cycle, respectively, indicating possibility in improving grain yield with further cycle of selection. Besides grain yield, plant and ear height were the major traits for which improvement was sought in this population improvement programme.

Plant height has, however, showed less realized heritability than ear height indicating less progress even with further cycles of selection. This was expected because in UCB there is very high correlation between grain yield and plant height. Hence, tall plants with reasonably lower ear placement and better cob size were selected for, not to sacrifice grain yield while selecting for short plant height.

The magnificent reduction in ear height has contributed positively to improve resistance to lodging as a correlated response to selection. It was observed that high ear placement was the main character causing lodging in UCB more than tall plant height since with no much reduction in plant height resistance to lodging, though not statistically significant, improved together with 20 % reduction in ear height. Similar to resistance to lodging disease resistance also improved as a positive and correlated response to selection. Severity of gray leaf spot (GLS) reduced significantly from 2.2 in UCB C_0 to 1.8 in UCB $S_1 C_2$. In maize inheritance of resistance to gray leaf spot is governed by recessive genes of quantitative and additive nature (Ulrich et al., 1990). Hence selfing followed by selection might have increased the frequency of homozygous recessive genotypes. In addition to improvement over the parent population, UCB $S_1 C_2$ had significant ($P<0.01$) grain yield benefits of 35.0% (3.0t ha^{-1}) and 29.3% (2.6t ha^{-1}) relative to Gibe Composite 1 and Kuleni, respectively.

This has clearly indicated that UCB $S_1 C_2$ can be used in place of these open pollinated varieties at least in the mid altitude (1600-1800 masl) agro ecologies in the southwestern part of Ethiopia. The improvement made has also put UCB $S_1 C_2$ in a position to compete with the commercial hybrids, BH660 and BH670. The parent population was yielding lower than both hybrids with no statistically significant yield difference. After two cycles of selection, however, gain of 2.0t ha^{-1} has put UCB $S_1 C_2$

in a position to yield higher than the two hybrids even though the yield difference was still not statistically significant. In the Ethiopian national maize breeding programme, it has not been a common experience to see open pollinated varieties yielding higher than hybrid varieties.

Higher yield of UCB S_1 C_2 observed in this study can be ascribed to certain phenotypic characters that have been improved to the extent that the resemblance between UCB S_1 C_2 and the two hybrids has been improved. The improvement program has removed extremely tall phenotypes with high ear placement and this has brought down the ear placement and plant height which have inturn improved resistance to lodging. In addition, being late maturing types both were competent enough in equally exploiting the longer growing period. Above all it is the efficient and comparable sink-source relationship that has empowered the improved version to be competent with the hybrids in productivity.

Considering the improved yield potential and other desirable traits UCB S_1 C_2 was proposed for release. Hence, UCB S_1 C_2 was promoted to verification trials and presented to the National Variety Releasing Committee (NVRC) evaluation for release as an opv. Mean data on major agronomic characters and grain yield measured in two on station and four on farm verification sites is indicated on Table 5. These data have clearly substantiated the improvement that has been observed in on station research plots. UCB S_1 C_2 has maintained its superior performance relative to the parent population and the two commercial opvs, Gibe Composite 1 and Kuleni. Earliness, moderate ear placement and plant height, and resistance to lodging and diseases, and attractive ear characters were found to be the desirable traits that confirmed its superior performance. Contrary to on station results mean plant and ear height measured in verification trials showed much more improvement.

Both traits showed corresponding reduction of 24.8% (87cm) and 14.2% (32 cm) from 350 and 226 in UCB C_0 to 263 and 194 cm in UCB S_1 C_2 indicating the suitability of UCB S_1 C_2 to the real farmers' field condition. In line with this, significant improvement in resistance to lodging has been noticed. It was more interesting to see the genetic gain of 2.0t ha^{-1} gained in research plot to be repeatedly measured in larger plots. This clearly indicated that genetic improvement has played significant role in improving productivity by 2.0 tones as both the parent population and UCB S_1 C_2 were evaluated under similar management and environment both in research center and farmers' field.

This yield benefit is, however, limited to the mid altitude (1600-1800 masl) agro ecologies of Jimma and Illubabore zones and similar areas in the southwestern part of Ethiopia. Moving this variety out of this altitudinal range in either direction may cause yield reduction. In higher altitude, turcicum leaf blight (TLB) was observed to be the limiting factor. In lower altitude the variety may grow tall and lodge because of heavy winds combined with rainfall. This recommendation has been approved by the NVRC during its meeting when the variety was official approved for full release in February 2008. The variety was named as 'Morka' meaning competent, to express its yield potential which is comparable with the yield potential of popular hybrid varieties in the regions.

CONCLUSION

It can be concluded that two cycles of S_1 recurrent selection have brought significant genetic improvement in the major agronomic characters and grain yield in UCB. The improved version was released and recommended for production with two cycles of improvement before reaching the yield plateau. This was mainly due to two reasons. First there is urgent need to have open pollinated variety in place as an option to BH660 which is the popular hybrid in Jimma and Illubabore zones and the southwestern part of the country as a whole. Second it was felt important to reserve some level of variability in the population to overcome some production challenges that may come up in the future.

At present further improvement is important to break the linkage between plant and ear height, and grain yield to develop early version of UCB S_1 C_2. The selection scheme used is known for improving resistance to inbreeding depression and inbred lines developed from the improved population may have better seed production potential. Hence it can be used as source of inbred lines in hybrid development program. However, the genetic purity of the variety has to be maintained following standard method of maintaining open pollinated variety. The seed can be formally or informally produced on farmers' field with sufficient isolation from other maize fields. A link has already been established with the formal seed system to multiply and avail seed to users. The Ethiopian Seed Enterprise (ESE) has multiplied seed in 60 ha in the main season of 2008 in Jimma and Illubabore zones in collaboration with the Ministry of Agriculture and Rural Development Offices of the two zones. Morka has, therefore, been distributed to farmers in the main season of 2009 as an option to hybrid varieties.

Table 1: Combined analysis of variance for grain yield and other traits evaluated across five environments

Sources of variation	DF	Mean squares								
		Grain Yield	Days to 50% silking	Plant height	Ear height	Ear position	Lodging per cent	Diseases (1-5 scale)		
								GLS	TLB	CR
Environments (E)	4	10674.1**	4348.5**	15761.1**	12113.7**	0.034**	847.8*	0.015	0.104**	0.125**
Error	15	92.84	6.47	407.6	354.6	0.003	217.4	0.021	0.005	0.008
Genotypes (G)	7	1956.4**	94.4**	7574.8**	9767.7**	0.03**	102.2	0.124**	0.063**	0.061**
G X E	28	218.3**	31.0**	560.6	565.8**	0.005	155.8*	0.016**	0.010**	0.013**
Error	105	98.3	2.9	456.4	289.8	0.003	97.9	0.007	0.005	0.005
CV (%)		13.8	1.81	7.34	10.2	10.10	38.7	6.41	5.11	6.26

*, ** statistically significant at P <0.05 and 0.01 probability level, respectively

GLS: Gray leaf spot, TLB: Turcicum leaf blight, CR: Common rust

Table 2: Mean grain yield and major agronomic traits of different selection cycles and the standard checks combined across five Environments

Entries	Grain Yield (t ha^{-1})	Plant height (cm)	Ear height (cm)	Ear position	Days to 50% silking	Diseases (1-5 scale)			Lodging (%)
						GLS	TLB	CR	
UCB C_o	6.7bcd	320.6a	201.7a	0.63a	97a	2.15(1.33)b	2.38(1.37)bc	1.23(1.07)bc	17.36(22.8)
UCB $\mathbf{S_1}$ C_1	7.5abc	307.3ab	182.5b	0.57b	97a	2.08(1.30)bc	2.25(1.35)d	1.20(1.07)c	20.61(25.5)
UCB S_1 C_2	8.7a	289.8bc	162.1c	0.55bc	94bc	1.83(1.25)c	2.00(1.30)d	1.15(1.05)c	14.99(21.4)
BH660	7.9ab	302.2bc	179.7b	0.60ab	95b	2.08(1.31)bc	2.10(1.32)d	1.25(1.09)bc	22.47(27.4)
BH670	7.7ab	292.4bc	168.4bc	0.53cd	96ab	2.08(1.31)b	2.15(1.33)b	1.10(1.04)b	12.65(27.0)
Kuleni	6.2cd	263.3d	138.4d	0.58b	91d	2.25(1.34)bc	2.40(1.38)bcd	1.33(1.11)c	23.04(27.4)
Gibe composite-1	5.7d	266.7d	135.9d	0.52d	93c	2.33(1.51)a	3.05(1.47)a	1.68(1.21)a	20.27(27.2)
Mean	7.2	291.0	166.8	0.57	95b	(1.30)	(1.35)	(1.09)	(25.5)
F-test	**	**	**	**	**	**	**	**	ns
LSD1%	1.4	17.7	14.1	0.045	1.43	0.069	0.01	0.058	
CV(%)	13.91	7.34	10.21	10.1	1.8	6.81	5.11	6.26	38.69

** Differences are statistically significant at p<0.01 probability level; ns:

No statistically significant differences among the entries

Values followed by the same letter(s) are not significantly different from each other

GLS: Gray leaf spot, TLB: Turcicum leaf blight, CR: Common rust

Values in parenthesis indicate transformed data

Source: Field experiment, 2005 - 2007

Table 3: Genetic gains (%) achieved in grain yield and other agronomic traits with two cycles of S_1 recurrent selection in UCB.

Traits	Cycle 1	Cycle 2	Overall gains	Average
Grain yield	11.1	16.4	29.3**	14.0
Ear height	-9.5**	-11.2**	-19.6**	-10.3**
Plant height	-4.14	-5.7	-9.6**	-5.0
Ear position	-9.5**	-3.5	-12.6**	-6.3
Days to 50 % silking	0.0	-3.1**	-3.1**	-1.55
Disease severity				
Gray leaf spot	-3.3**	-12.0	-14.9**	-7.5
Turcicum leaf blight	-5.5**	-11.1**	-16.8**	-8.4
Common rust	-2.4	-4.2	-6.5	-3.3

** Gains are statistically significant at P<0.01 probability level

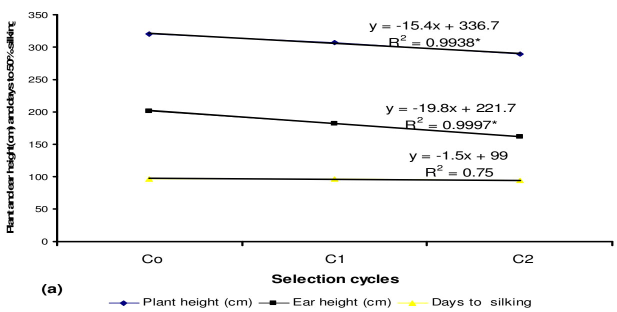

Figure 1: Trends of grain yield and important agronomic traits with cycles of selection

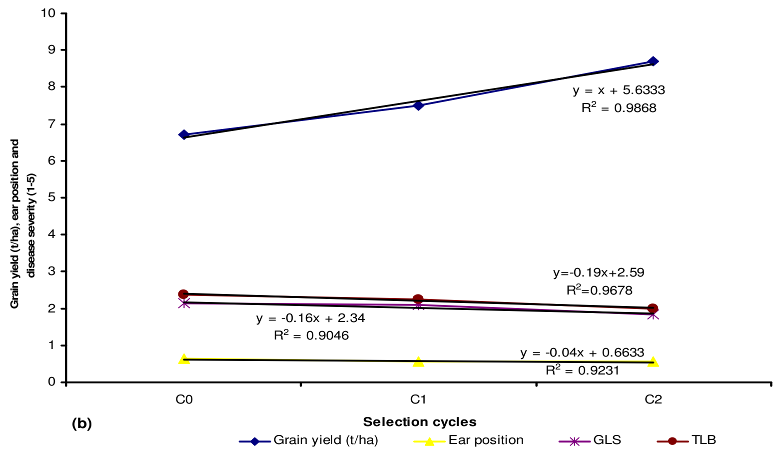

Figure 1: Trends of grain yield and important agronomic traits with cycles of selection

Table 4: Selection differential(**S**), responses to selection (**R**) and realized heritability (**h^2r**) achieved in different traits in two cycles of S_1 recurrent selection in UCB

Cycle 1	Days to 50% silking	Ear height (cm)	Plant height (cm)	Diseases (1-5 scale)*			Grain yield ($t\ ha^{-1}$)
				GLS	TLB	CR	
C_0 ($\bar{X}_0$)	97	201	320	2.15	2.38	1.23	6.7
$\bar{X}_{se}$	90	151	256	1.8	1.6	1.4	5.0
$\bar{X}_1$	97	182.5	307.3	2.08	2.25	1.2	7.5
S= $\bar{X}_{se}$ - $\bar{X}_0$	7	50	64	0.35	0.78	0.17	1.72
R= $\bar{X}_1$- $\bar{X}_0$	0	18.5	12.7	0.07	0.13	0.03	0.75
h^2r= R/S	0	0.37	0.19	0.2	0.17	0.17	0.44
Cycle 2							
C_1 ($\bar{X}$ 1)	97	182.5	307.3	2.08	2.25	1.2	7.5
$\bar{X}_{se}$	91	134	237	1.5	1.5	1.0	6.0
$\bar{X}_2$	94	162.1	289.8	1.83	2.0	1.15	8.7
S= $\bar{X}_{se}$ - $\bar{X}$ 1	6	48.5	70.3	0.58	0.75	0.20	1.47
R= $\bar{X}_2$- $\bar{X}$ 1	3	38.9	17.5	0.25	0.25	0.05	1.23
h^2r= R/S	0.5	0.42	0.24	0.43	0.33	0.25	0.84

GLS: Gray leaf spot, TLB: Turcicum leaf blight, CR: Common rust

*1 indicates clean or no infection and 5 severely diseased

$\overline{X}_0$: Mean of the parent population,

$\overline{X}_1$: Mean of cycle one,

$\overline{X}_2$: Mean of cycle two,

$_{se}$: Mean of families selected as parents of the respective selection cycles

Table 5: Mean data combined across two on station and four on farm sites in variety verification trial

No.	Entries	Days to 50% silking	Plant height (cm)	Ear height (cm)	Diseases (1-5)*			Lodging (%)	Plant aspect (1-5)**	Ear aspect (1-5)**	Diseased ears (No)	Bare tips (No.)	Grain yield (t ha^{-1})
					GLS	TLB	CR						
1	Kuleni	74	270	149	2.2	2.2	1.0	9.4	3.0	2.5	15	8	5.1
2	Gibe Composite 1	76	266	123	3.2	2.6	1.5	7.5	3.0	2.6	31	10	3.8
3	UCB C_O	91	350	226	2.0	2	1.0	34.3	3.0	2.2	6	0	4.2
4	Morka	79	263	194	1.5	1.5	1.0	2.6	1.4	1.4	3	0	6.2

GLS: Gray leaf spot, TLB: Turcicum leaf blight, CR: Common rust

*1 indicates clean or no infection and 5 severely diseased

** 1 is good and 5 is poor

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