RESPONSES TO AGGREGATE TRAIT SELECTION FOR *CHILO PARTELLUS (*SWINHOE) RESISTANCE IN MAIZE (*ZEA MAYS L.)* POPULATION

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Selection indices are efficient ways of simultaneously improving a number of quantatively inherited traits in maize (*Zea Mays* L.). Different selection indices have been improved (Smith, *1936; Hazel,1943; Williams,1962) while Elston(1963) further improved on these by proposing weight free indices. More recently, Mulamba and Mock (1978) developed a parameter free index, the rank summation indices (RSI) to improve density tolerance in maize (*Zea Mays* L.). However, further studies comparing relative efficiencies of different indices suggest that simpler indices, that are parameter and weight free, are favoured (Subandi et al 1973; crosbie et al 1980).

Relative efficiency of a breeding procedure is dependent on the rate of improving and ease of handling. Predicting responses to selection helps in comparing different methods. Studies predicting progress from a single trait selection are common in literature but those predicting responses to index selection are very few. Crosbie et al (1980) observed that linear index proposed by Baker (1974), the Elston (1963) weight free index(EWF) and rank summation(RSI) of Mulamba and Mock(1978), combined simplicity of use, freedom from use of estimate genetic parameters, good selection differential and predicted gains in each trait and in the aggregate genotype. Pesek and Baker (1969a) proposed the formula for predicted gain for each trait due to index selection while Mock and Eberhart (1972) further suggested a formula for calculating predicted gain in the aggregate trait and concluded that index selection for cold tolerance was about as efficient as single trait selection. Opeke (1983) noted that responses to index selection for seedling vigour though inferior to single trait selection would improve grain yield. Subandi et al (1973) observed that results from earlier studies on selection indices could be summarized as follows: in general,the index was superior to other selection procedures in both predicted and actual genetic advances ,an index aimed at improving a trait gives greater gains than selection based only on that trait and for an index to be effective, the genetic correlations between the trait included in the index and the traits to be changed must be high.

ICZ3(IC-90-W1), a white grained early to medium population was used in this study. A total of 144 S_2 lines and 140 S_2 test cross progenies derived from ICZ3 were evaluated for damage parameters (leaf feeding, dead heart and stem tunneling) caused by *Chilo partellus* and agronomic traits including gain yield in two locations. The experimental locations were (MPFS) and Ungoye which are ICIPE testing sites. Mbita Point field Station has bimodal rainfall distribution with two distinct peaks. The early season (long rains) starts from late march and ends in late September or early October, the late season (short rains) starts from late September or early October to December.

It is situated on the shores of lake Victoria in Western Kenya (latitude 0^0 25′-0^0 30′ South, Longitude 34^0 15 East and altitude 1240M. Ungoye is 35 KM from Mbita Point field Station with similar rainfall distribution pattern and also situated along the lake region.

In each site, the 144 S_2 lines and 140 S_2 test cross progenies were planted in two replicate experiments. The genotype were grown in a randomized complete block design with single row plots. Each row was 5.0m long but separated into two 2.25m halves with a space of 0.5m in the middle. Spacing was 0.75m between rows and 0.25m between hills. Each hill was planted with two plants but later thinned to one three weeks after germination to give a maximum of 10 plants/2.25m row and a density of approximately 53,333 plants/ha. All plants in one half of the row were artificially infested with 30 first instar *C.partellus* larvae reared on artificial diet (Ochieng etal1985) three weeks after emergence. Appropriate culture practices, such as fertilizer application, weeding, bird or monkey scaring were carried out as deemed necessary during the season.

Data on foliar lesions and dead heart were taken at four weeks after infestation. Foliar lesions was score on a 1-9 scale (1=resistant and 9=susceptible) while dead heart was assessed as the proportion of plants in a plot showing the symptom. Extent of stem tunneling by the larvae was estimated at harvest as the percentage of the plant height. Other agronomic data recorded were plant height, stand at harvest, number of ears harvested, mean length of five ears per plot, moisture content at harvest and grain yield. Grain yield was obtained as grain weight adjusted to 13% moisture content. Yield reduction was calculated as the difference between the yield of the un infested control and the infested. Dead heart and stem tunneling data for each location were transformed into arc-sine values before subjecting to analysis of variance (ANOVA). On this transformed scale, error variances were highly homogenous according to Barlett's test (Barlett, 1939). Combined ANOVA was therefore carried out. Two Rank Summation Indices (RSIs) were constructed to determine the ranking of each line within the population for suitable response. The first index(RSI-1) was obtained by ranking the means of each leaf feeding (LF), dead heart(DH) and stem tunneling(ST) for each line, summing the ranking of the line to obtain its aggregate performance compared with other lines within the same population. A second (RSI-2) was obtained using the three traits and grain yield. Rank Summation Index (Mulamba and Mock, 1978) was summarized as follows;

$$RSI=\Sigma Ri's$$

Where Ri is the rank of the mean of each of the desired traits.

RS1-1=Aggregate performance of a genotype using the ranking of leaf feeding, dead heart and stem tunneling.

RSI-2= Aggregate performance of a genotype based on ranked means of leaf feeding, dead heart, stem tunneling and grain yield. Thus the lowest possible values for the two indices would be three and four respectively, characterizing a line in a line particular progeny type that ranked first for all traits. An entry with the least damage for foliar feeding, dead heart and stem tunneling and highest grain yield will rank first for the four traits.

Expectations of mean squares (EMS) from analysis of variance were used to estimate genotypic ($\sigma^2 g$), genotype x environment ($\sigma^2 ge$) interaction, error (σ^2) and phenotypic ($\sigma^2 ph$) components of variance, while expectations of mean cross products (EMCP) from analysis of covariance were used to estimate genotype correlations. Standard errors (S.E) for each of the variances ($\sigma^2 i$) except phenotypic variance were calculated as (Hallauer, 1971):

$$\text{S.E. } \sigma^2 i = [2/C^2 \{msi^2/(dfi=2\}]^{1/2}$$

While that for phenotypic variance was computed as

$$\text{S.E } \sigma^2 ph = [(1/re^2)\{msg/(dfi+2)\}]^{1/2}$$

where msi, dfi and C^2 are mean squares, degree of freedom and coefficient of the component in the EMS for trait I respectively, and msg is the mean square for genotype, r=number of replicates and e=number of environments or locations. Habitability (σh^2) estimates were calculated as proportions of total variance due to genetic causes with S.E also calculated as proportions of S.E of $\sigma^2 g$ to σ^2 ph. Entry means across locations and replicates were used to calculate simple correlations and step wise multiple regressions. Predicted responses (ΔG) for single trait selection were calculated as:

$$(\Delta G) = k.\ ph.\ h^2$$

Where k (k=1.76 for selection intensity of 10%) is the standard selection differential, ph is the phenotypic standardized deviation and h^2 represents heritability for the trait under consideration.

RSI values were subjected to both analysis of variance and covariance and the information obtained from EMS and EMCP were used to estimate variance components and heritability. Predicted response to selection for RSI was then calculated using the above formula. This was then compared with the formula of

Mock and Eberhart (1972) for calculating gains from aggregate selection as follows:

$\Delta H = ai\Delta gi$

Where is the economic weight for the ith and Δgi, which was calculated, using the formula of Pesek and Baker (1969a), is the predicted response for trait due to index selection.

Economic weights were –1,-1,-1 and 1 for foliar, dead heart, stem tunneling damages and grain yield, respectively. Coefficient (b values) used in the estimation were obtained by solving the equation bi= $(Xij)^{-1}$(gij)(ai) where Xij and gij are variance covariance matrices of phenotypic and genotypic values respectively for the four traits in each of the progeny types.

Correlated responses due to single and aggregate trait selection created by RSI were calculated as:

$CR_{y(x)} = i_x.h_x.h_y.r_{gx.y}$ phy (Falconer, 1960)

Where ix= selection intensity applied to trait x, $.h_x$ and $.h_y$ are square roots of heritability estimates for traits x and y, respectively, $r_{gx.y}$ is the genetic correlation between the two traits, and phy is the square root of phenotypic variance for trait y.

Estimates of perimeter components of variance obtained for each of the two progeny types presented in Table 1. for most traits, genetic(σ^2e) and environmental(σ^2e), and phenotypic (σ^2ph) variances exceeded twice their standard errors. Generally, the genotypic variances for most traits were large enough for selection purposes. Except for a few cases the estimates of genotype by environment variances (σ^2ge) were either negative or smaller than their respective standard errors (se). Also, most of the genetic variances were larger for S_2 progeny types than for the test cross hybrids corresponding to high heritability estimates in the former than the later. Heritability estimates for parameters of resistance, grain yield and selection indices in most cases were moderate for the S_2 families thus suggesting that simultaneous improvement of these traits in the desired direction should be possible, and especially so with the use of selection indices to effectively combine the traits. However, for the test cross hybrids, the estimates were low for the majority of the traits.

√ TABLE 1:

Correlations of parameters of resistance to C. partellus (leaf feeding and stem tunneling) with mature plant characteristics, including grain yield (Table 2), were generally negative. Dead heart showed highly significant correlations with stand count, ear length, ear number and moisture % at harvest for the two progeny types. Rank summation index(RSI-1) involving the three parameters of resistance namely, leaf feeding, dead heart and stem tunneling showed highly significant ($P<0.01$) correlations with the four agronomic traits as opposed to those involving RS-2, which were generally negative apart from a few cases.

√ TABLE: 1. Genotypic (σ^2g) genotype X environment (σ^2ge) interaction, error (σ^2e), phenotypic (σ^2ph) variances and heritability(h^2) estimates of traits and Rank Summation Index(RSI) in each of the two progenies

Progeny	Trait	σ^2g	σ^2ge	σ^2	σ^2ph*	h^2
Test crosses	Leaf feeding	0.01±0.02	-0.07±0.05	0.95±0.08	0.21±0.05	0.05±0.09
	Dead heart%	0.01±0.01	0.01±0.02	0.27±0.02	0.09±0.02	0.11±0.11
	Stem tunneling	0.45±0.43	0.90±0.74	10.86±0.82	3.62±0.86	0.12±0.11
	Grain yield(t/ha)	0.10±0.12	0.15±0.22	3.51±0.29	1.05±0.25	0.10±0.11
	Plant height(cm)	314.03±214.53	424.40±354.79	5151.24±430.77	1814.04±304.60	0.17±0.12
	Rsi-1	40.61±16.54	-38.62±40.27	3956.47±332.02	1010.42±229.15	0.40±0.02
	Rsi-2	6.55±2.12	-4.90±5.24	5071.93±425.63	1272.08±300.68	0.01±0.002
S_2 lines	Leaf feeding	0.03±0.03	0.06±0.04	0.64±0.06	0.11±0.05	0.27±0.27
	Dead heart%	0.01±0.01	-0.01±0.02	0.45±0.04	0.11±0.03	0.09±0.09
	Stem tunneling	1.12±0.99	-0.56±1.24	21.47±1.86	6.21±1.47	0.18±0.16
	Grain yield(t/ha)	0.20±0.11	-0.11±0.14	2.51±0.22	0.78±0.18	0.26±0.14
	Plant height(cm)	118.860±33.33	23.25±29.99	444.54±38.55	241.37±1.84	0.49±0.14
	Rsi-1	18.05±15.40	-17.98±30.80	3604.90±309.12	910.29±218.87	0.02±0.16
	Rsi-2	405.30±223.71	-790.60±447.43	5173.87±443.66	1303.47±361.54	0.31±0.17

*= σ^2ph obtained as σ^2g +σ^2ge/r+ σ^2/re

TABLE 2: Simple linear correlations of Chilo partellus resistance parameters including rank summation index (RSI) on mature plant traits and gain yield from test cross hybrids and S2 progenies combined for Mbita Point Field Station (MPFS) Ungoye locations of western Kenya

Trait	Progeny type	Leaf feeding	Dead heart	Stem tunneling	RSI-1	RSI-2
Plant height(cm)	(i)	0.11	-0.07	0.29**	-0.13	0.00
	(ii)	0.05	-0.03	0.22**	-0.13	-0.02
Stand count	(i)	-0.09	0.19*	-0.11	0.31**	-0.04
	(ii)	-0.08	0.30**	-0.08	0.48**	0.08
Ear length	(i)	-0.07	0.40**	-0.09	0.95**	-0.13
	(ii)	-0.14	0.32**	-0.15	0.99**	0.21**
Ear number	(i)	0.01	0.26**	0.09	0.34**	-0.14
	(ii)	-0.01	0.25**	-0.03	0.45**	0.12
Moisture (%)	(i)	-0.09	0.27**	-0.14	0.49**	-0.14
	(ii)	0.04	0.24**	-0.14	0.61**	-0.02
Grain yield(t/ha)	(i)	-0.03	-0.04	-0.05	-0.01	-0.08
	(ii)	-0.01	-0.03	-0.04	-0.02	0.04

*,** significant at $P<0.05$ and 0.01, respectively. (i)=testcrosses (ii)= progenies

The possible contribution of each of the damage parameters to grain yield reduction was examined using step-wise multiple regressions. Results obtained (Table 3) indicated that in the testcrosses, stem tunneling accounted for at least 45% of the total variation in grain yield reduction (R^2=0.45). In the two progeny types, stem tunneling had the greatest contribution towards grain yield reduction (R^2 being 0.36 for S_2 lines and 0.45 for the testcross)

TABLE 3: Unstandardized partial regression coefficients (b-values), coefficients of determination (R^2) and R^2 change ΔR^2 from step-wise multiple regression of grain yields on parameters of resistance in each of the progeny types.

Family type	trait	b-value	R^2	$\triangle R^2$
Test crosses	Leaf feeding	-0.01	-0.01	0.01
	Dead heart%	1.40	0.01	0.00
	Stem tunneling	-0.14	0.45	0.44
S_2 lines	Leaf feeding	0.002	0.20	0.20
	Dead heart%	-0.09	0.27	0.07
	Stem tunneling	0.02	0.36	0.09

Predicted direct responses to selection for gain yield, parameters of resistance i.e. leaf feeding, dead heart and stem tunneling due to index selection were much lower than when single trait selection was carried out for each of the traits (Table 4). Opeke (1983) noted that relative to single trait selection, index selection usually gave lower progress for selection because superiority of a trait is negated by mediocrity in other traits in the index. Response due to index selection (ΔH) was higher for test cross hybrids than that of the S_2 progenies while Rank Summation Index (RSI), more progress was achieved in S_2 progenies than in the test cross hybrids. In effect, although either of the methods would result in aggregate improvement , actual gains in each progeny would depend on the selection method used. Rank Summation Index (RSI) gave more than double the progress of the aggregate trait selection in S_2 progenies (Table 4).

TABLE 4: Predicted direct response(△ G/CYCLE) to single trait selection for parameters of resistance, the aggregate trait Created By Rank Summation Index (RSI) and to index selection in each of the two progeny types.

Family type — gains from selection

Single trait selection

Family type	Grain yield(t/ha)	Leaf feeding	Dead heart(%)	Stem tunneling(%)	RSI
Test crosses S_2 lines					4.48
	0.32	-0.08	-0.12	-0.22	10.75
	0.40	-0.16	-0.05	-0.79	

Index selection

	Grain yield (t/ha)	Leaf feeding	Dead heart(%)	Stem tunneling(%)	ai △ gi
Test crosses S_2	0.12	-0.09	-0.06	-0.08	4.20
Lines	0.10	-0.08	-0.04	-0.63	3.55

Predicted correlated responses in grain yield when selection was done for parameters of resistance and the rank summation indices are presented in Table 5. When these gains were expressed as percentage of the means of their respective families in the two progeny types, they were lower than those expected from direct selection for grain *per se*, in all cases, except, for RSI-2 in S_2 families.

TABLE 5: Predicted correlated responses (per cycle) in grain yield (t/ha) when selection was done for parameters of Resistance including summation index (RSI) in ICZ3 population.

Selection criteria	test cross hybrids	S2 families
Leaf feeding	-0.02 (-0.84)	-0.05 (-2.04)
Dead heart (%)	(-3.45)	-0.23
Stem tunneling (%)	-0.25 (-4.32)	(-9.39) -0.32
RSI-1	-0.002 (-0.03)	(-13.06) -0.001
RSI-2 (	-0.64 (-11.50)	0.20 (8.16)

()= Correlated responses expressed as % of the overall mean yield of the respective progeny type

Studies suggesting approaches aimed at reducing limitations associated with selection index construction have been reported (Williams, 1962; Elston,1963; Pesek and Baker, 1969b,1970) but problems in assigning appropriate economic importance (weight) to each trait and those associated with extensive computation still exist. RSI therefore, has the advantage of not only giving appreciable progress for aggregate gain but also the ease with which they can be handled.

Aggregate trait selection in the progeny types would result in the improvement of other traits including those not include in the formation of the index e.g grain yield and plant height.

However, increase in height is an undesirable character commonly associated with yield in tropical maize germplasm (Miranda Filho, 1985). Excessively tall plants can lead to stalk lodging especially in windy weather (Ajala, 1990). The association or correlated response to selection of a trait or other unselected traits occur either due to linkage response to selection of a trait or other unselected traits occur either due to linkage or pleiotropy (Fakorede and Mock,1982). Correlation between the resistance parameters and the selection indices with mature plants traits including grain yield were generally very low, except for a few agronomic traits, implying that damage levels could not be used as a measure of expected grain yield for the materials studied. Such findings are in agreement with that of Ajala et al (1993).

Since grain yield is of paramount importance to the breeder, possible contribution of each of the damage parameters examined using step-wise multiple regressions indicated that in both the test crosses and S_2 progenies leaf feeding seemed to contribute less towards yield reduction than stem tunneling and dead heart. Mohyuddin and Attique (1978) and Pathak and Othieno(1990) attributed yield reduction in maize to be caused more by dead heart. Results obtained in this study do not seem to occur with the observation of these researchers. However, Ajala and Saxena(1994) using correlations, step wise multiple regressions and path coefficient analyses to study the interrelationship among the three damage parameters (foliar lesions, dead heart and stem tunneling) and their contribution to grain yield reduction showed that yield loss caused by *Chilo partellus* is primarily due to stem tunneling of the plants.

The primary objective of the study was to improve maize population (ICZ3) for resistance to the spotted stem borer, *Chilo partellus.* Data presented herein showed that use of RSI is feasible and will improve grain yield. Use of index coefficients requires that appropriate economic weights be placed on each progeny type and determination of the economic importance (weight) for each trait is arbitrary. This therefore strengthens the argument in support of RSI as a better index.