SHORT NON-REFEREED PAPER

REALISED SELECTION GAINS FOR *ELDANA SACCHARINA* BORER RESISTANCE IN THE COASTAL LONG CYCLE REGIONAL BREEDING PROGRAMME OF SOUTH AFRICA

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Introduction

The *Eldana saccharina* Walker (Lepidoptera: Pyralidae) (eldana) stalk borer is the most important insect pest of sugarcane in South Africa. Eldana larvae damage sugarcane by boring and feeding on the tissue inside the stalks resulting in sucrose losses. The South African Sugarcane Research Institute (SASRI) started breeding for eldana resistance in the 1980s when it became an economic pest of sugarcane (Nuss and Atkinson 1983; Nuss 1991). Crossing parents with low eldana damage and testing genotypes in artificial inoculation trials (Nuss and Atkinson, 1983) was used to identify resistant cultivars. Recently, family evaluation and selection for eldana damage has been explored (Zhou, 2015; Zhou and Mokwele, 2015). Progress in resistance breeding produced resistant varieties.

Realised genetic gain is the change in genetic value of a population over at least one cycle of selection for a particular trait or index of traits. Realised selection gains refer to the gains attained after several cycles of breeding and selections. It measures the success of recurrent selection among breeding programmes (Lingle *et al.,* 2010). Studies on realised selection gain have been reported for other traits such cane yield, sucrose and sugar yield (Burnquist *et al.,* 2010; Zhou 2015). The objective of this study was to determine realised selection gains for eldana resistance.

Material and Methods

Trial sites

Data were collected from the coastal long cycle breeding programme trial series planted from 2008 to 2012 and harvested from 2010 to 2017 at five trial sites. The trials were planted at Gingindlovu and Kearsney research stations and three off-station sites, one near Kearsney and two near Gingindlovu. Gingindlovu (93 m altitude; 29°03'S; 31°59'E) represents the coastal average potential area and Kearsney (241 m altitude 29°17') represents the coastal hinterland area. These locations represent areas where sugarcane is grown under rainfed conditions and harvested at 15 to 18 months (Nuss, 1998). Sugarcane in these areas is prone to high eldana infestation due to the long cutting cycle. Atkinson and Nuss (1989), Way and Goebel (2003) and Goebel *et al.,* (2005) reported high eldana infestations in older cane than in younger cane due to its ability to breed and increase its population.

Experiment design, data collection and analysis

All the trials were laid out as randomised block designs with three replications, and plot sizes of 5 rows by 8 m, spaced at 1.2 m apart. The genotypes in trials ranged from 24 to 36. At harvest, 20 stalks per plot were randomly sampled, the number of bored stalks recorded and converted into percentage bored stalks (PBS). (Leslie, 2013). The total number of internodes were counted, then the stalks were longitudinally split and number of internodes with borer entry and exit holes were inspected and recorded. The result was then converted into percent internodes bored (PBI) by dividing the number of bored internodes by the total number of internodes and multiplied by a hundred. Data were analysed using the Statistical Analysis System (SAS institute, 2014) using the linear mixed model:

$$Y_{ijkl} = \mu + L_l + R(L)_{k(l)} + G_i + GL_{il} + GR(L)_{ik(l)} + C_j + LC_{jl} + CR(L)_{jk(l)} + GC_{ij} + GLC_{ijl} + E_{ijkl} \quad \text{Equation 1}$$

where, Y_{ijkl} = the observation for genotype i (i = 1,2,3….g) in C_j = crop year j (j = 1,2,3....c), at L_l = location l (l = 1,2,3…l), in R_k = replication k (k = 1,2,3), L_l = the fixed effect of the lth location, $R(L)_{kl}$ = the random effect of kth replication nested within lth location, Gi = the fixed effect of the ith genotype, GL_{il} = the fixed effects interaction effect between the ith genotype in the lth location, $GR(L)_{ikl}$ = the random interaction effect between the ith genotype and the kth replication nested with the lth location, C_j = the fixed effect of the jth crop-year; LC_{jl} = the fixed interaction effect between the lth location and jth crop, $CR(L)_{jkl}$ = random interaction effect between the jth crop year and the kth replication nested within the lth location, GC_{ij} = the fixed interaction effect between the ith genotype and the jth crop year; LGC_{lij} = fixed interaction effect between the lth location and the ith genotype and the jth crop year, and E_{ijkl} = residual error.

The least square means across sites and crop years were expressed as a percentage of NCo376 (long-term control). The means (% NCo376) were used as the response variable, while the year of selection of planting the series of the trial was used as the predictor variable to perform simple linear regression analysis using SAS. The simple linear regression model used was:

$$Yi = a + bxi + ei \quad \text{Equation 2}$$

where Yi was the genotype means (% NCo376) for PBS and PBI; a was the intercept for the ith series; b was the slope; xi was the ith year of planting and also the predictor variable; ei was the residual error.

Results and Discussion

Location (L), location by genotype (GL), crop year (C), crop year by genotype (CG), crop year by location (CL), and location by crop year by genotype (GLC) produced highly significant ($P<0.001$) F-values for both PBS and PBI in all series (Table1). The F values for genotype effects were the highest. The highly significant genotype effects indicated differences among genotypes for PBI and PBS (Table 1). These also indicated the ability to discriminate and select for genotypes with less damage in each series. The significant L, C and CL effects, suggested that eldana damage levels were different across locations, crops and across crops at each location. However, crop year and location effects had the largest F values. Crop year effects are highly confounded by seasonal effects and cannot be exploited. The location effects suggested a need to identify more discriminating locations among high and low damage levels. Highly significant GLC showed a complex GE for eldana resistance.

Table 1. F-values and their P-values of per cent bored stalks (PBS) and per cent bored internodes (PBI) and simple linear analysis results for trial series in the coastal long-cycle programmes.

Effect	2008		2009		2010		2011		2012	
	F value	P value	F value	P value	F value	P value	F value	P value	F value	P value
PBS										
L	74.87	0.0001	311.64	0.0001	325.29	0.0001	338.89	0.0001	301.8	0.0001
G	9.13	0.0001	11.54	0.0001	32.81	0.0001	31.53	0.0001	36.45	0.0001
GL	1.63	0.0005	1.55	0.0014	2.49	0.0001	1.94	0.0001	4.00	0.0001
C	501.40	0.0001	171.61	0.0001	270.20	0.0001	567.73	0.0001	524.77	0.0001
CL	160.79	0.0001	43.53	0.0001	137.96	0.0001	52.24	0.0001	125.52	0.0001
GC	1.61	0.0024	1.76	0.0003	2.26	0.0001	2.01	0.0001	2.18	0.0001
GLC	1.28	0.0091	1.24	0.0213	1.22	0.0338	1.52	0.0001	1.35	0.0025
R^2	0.92		0.94		0.95		0.91		0.90	
CV	26.06		21.19		18.82		23.99		29.51	
PBI										
L	84.02	0.0001	44.47	0.0001	216.84	0.0001	188.39	0.0001	218.58	0.0001
G	8.28	0.0001	10.93	0.0001	40.36	0.0001	70.79	0.0001	58.01	0.0001
GL	2.27	0.0001	2.61	0.0001	5.62	0.0001	8.82	0.0001	8.04	0.0001
C	1040.49	0.0001	59.14	0.0001	243.58	0.0001	550.39	0.0001	491.68	0.0001
CL	280.59	0.0001	49.11	0.0001	66.54	0.0001	176.02	0.0001	152.97	0.0001
GC	3.53	0.0001	4.85	0.0001	4.06	0.0001	5.64	0.0001	8.65	0.0001
GLC	1.68	0.0002	2.14	0.0001	1.8	0.0001	4.04	0.0001	3.11	0.0001
R^2	0.95		0.96		0.93		0.93		0.91	
CV	36.58		33.67		34.49		37.40		47.78	
Simple Linear Regression										
			Estimate		Standard Error		T Value		Pr > |t|	
PBS	Intercept		1148.90		1736.03		0.66		0.509	
	Year		-0.527		0.86		-0.61		0.540	
PBI	Intercept		5844.45		3225.62		1.81		0.0720	
	Year		-2.866		1.605		-1.79		0.0761	

CV = coefficient of variance; L = location effects; G = genotypic effect; GL = location by genotype effect; C = crop effect; CL = location by crop effect; GC = genotype by crop effect; GLC = location by genotype by crop effect.

There were non-significant (P>0.076) reduction of 2.866% for PBI and non-significant (P>0.54) reduction of 0.527% in PBS per year, which suggested that there was limited improvement in reducing eldana damage in the populations (Figure 1). The results suggest that there was more reduction in the intensity of damage which is more yield limiting and less reduction in eldana incidence in the populations. These limited gains might be as a result of the complex GE factors that affect eldana resistance.

However, despite limited gains in eldana damage reduction, more varieties with eldana resistance have been released from the long coastal region breeding. This is possible as a result of the ability to select varieties with less damage indicated by highly significant genotype differences, hence some progress can still be achieved.

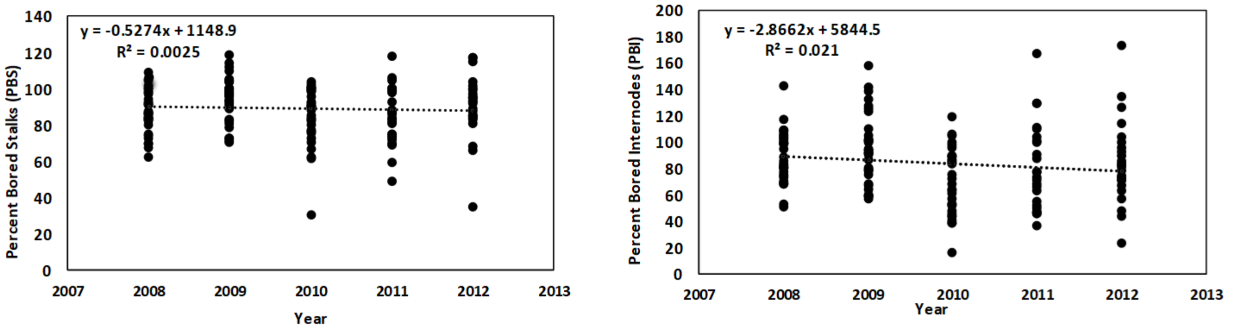

Figure 1. Percentage bored stalks (PBS) and percentage bored internodes (PBI) plotted over time.

Conclusion

The study showed limited improvements in reducing eldana damage in the breeding populations. However, some progress can still be achieved because high genotype differences, indicating the ability to select for low damage. The results highlighted the complexity of breeding for low eldana damage due to many factors that have to be taken into consideration.

Further studies need to be conducted to quantify the effect GE has on eldana resistance breeding.

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