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USING FOURTEEN SELECTION PROCEDURES TO EVALUATE PREDICTED AND REALIZED GENETIC GAIN IN THE COTTON CROSS GIZA 86 X SUVIN

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ABSTRACT

***Some selection procedures i.e. selection index involving 10 indices and pedigree line selection for four separately traits (lint yield/plant, bolls/plant, seeds/boll and lint/seed) were used to improve lint yield, yield components and fiber properties in early segregating generations; F_2, F_3 and F_4 of the cotton cross; (Giza 86 x Suvin). Performances of F_4 generation were higher than those of F_3 generation for lint yield/plant, bolls/plant, lint/seed, boll weight, seed index and fiber strength. Deviations of the realized advance from the predicted of lint yield determined in F_3 to F_4 generation were positive and high for all selection procedures. The realized efficiencies relative to pedigree selection for lint yield ($Ped._w$) were 283.3% for selection index involving bolls/plant ,seeds/boll and lint/seed (I_{1123}), 211.5% for selection index involving lint yield/plant and seeds /boll(I_{w2}), 211.5% for selection index involving lint yield/plant and lint/seed(I_{w3}) and 209.4% for selection index involving lint yield /plant ,bolls/plant and lint/seed (I_{w13}) in F_4 generation. Maximum gains for lint yield/plant, bolls/plant, boll weight, seed index and fiber strength were obtained when applying selection index I_{123}. However, pedigree selection for the traits; bolls/plant, seeds/boll and lint/seed are recommended in itself improvement. The path coefficients of lint with its components (bolls/plant, seeds/boll and lint/seed) were changed from F_2 to F_4 generations. This may be attributed to the efficiency** of selection procedures application in this study.*

Key words: ***Predicted gain, Realized gain, Path analysis, Selection procedures, Cotton.***

INTRODUCTION

Improving lint yield, yield components and fiber quality are important objectives in breeding cotton. Gain from selection in a breeding program depends on genetic variation within a population for a given trait, heritability of that trait, and selection intensity (Falconer 1981).

Selection index technique was proposed by Smith (1936) and Hazel (1943) to be used in the simultaneous improvement of several traits and to select for relatively more heritable correlated traits. A number of studies have reported on the selection index in cotton (Kamalanathan 1967, El-Kilany 1976, El-Okkia 1979, Mahdy 1983, Al-Rawi and Ahmed 1984, Hassaballa *et al* 1987, Mahdy *et al* 1987, Younis 1999, Gooda 2001, El-Lawendey 2003, Soliman and El-Lawendey 2008 and Kassem *et al* 2008). Numerous cotton research workers reported that lint yield, the most important economic trait in cotton, is a complex character and depends upon the action and interaction of a number of factors, hence Mahdy (1983) found

that the modified selection index was more efficient in improving lint yield and its components than the conventional index and single character selection. Also, he found that the selection index which involves lint yield, bolls/plant and lint/seed may be recommended .Al-Rawi and Ahmed (1984) indicated increases in efficiency of selection for yield from 1.4 to 34.0% for various indices. The index incorporated yield, bolls/plant and seeds/boll (I_{w12}) was superior to all other selection indices in the predicted advance and is recommended therefore. Mahdy *et al* (1987) compared several indices of selection. They reported that the selection index involving lint yield /plant, bolls/plant and lint/seed (I_{w13}) was the only one that gave significant increase of lint yield/plant (28.63%) and bolls/plant (20.08%) over mid-parent. Younis(1999) mentioned that the highest realized response obtained in the F_5 generation was 15.1%over the high parent in lint yield (index I_{w13}) and 21.5% in bolls/plant (index I_{12}).There were large discrepancies between predicted and realized gains. These results were expected because genotypic variances and covariances used to calculate predicted gains were likely biased by certain genotypic x environment interaction. On the other hand, El-Okkia (1979) and El-Lawendey (2003) showed that the highest predicted genetic advance for lint yield was achieved when selecting for yield alone. Selection for yield and the other two yield components (seeds/boll and lint/seed) resulted in reduction of predicted advance.

Pedigree line selection is preferred by plant breeders because it is versatile and makes the possibility of conducting genetic studies along with the plant breeding work. Thus, pedigree line selection with selection by independent culling levels has been utilized for cotton varietal maintenance in Egypt.

Path coefficient analysis was used to estimate the relative contribution of yield components to yield variation in cotton by several workers (Ghaly *et al* 1990, El-Beily *et al* 1996, Badr *et al* 1999, Asad *et al* 2002 and Soliman *et al* 2007) who reported that bolls/plant and lint/seed contributed the greatest part of variation to cotton yield. Smith and Coyle (1997) found that the cotton lint production and fiber quality are complex in nature. Linkage plays a role in the association of low fiber length and/or strength, and increased within-boll lint yield. Thus, breeding procedures that have been successful in breaking linkages of other characters should be successful in breaking these linkages also. The first objective of the research reported herein was to determine the predicted and realized gains from different selection procedures for improving lint yield. A second objective was to determine the correlated response between selected and unselected traits. A third objective was to determine the path analysis as affected by selection procedures.

MATERIALS AND METHODS

Genetic materials and selection procedures

The present study was carried out at Sakha Agricultural Research Station, during 2005, 2006 and 2007 growing seasons. The materials used were the F_2, F_3 and F_4 generations of intraspecific cotton (*Gossypium barbadense* L.) cross (Giza 86 x Suvin). Giza 86 was derived from the cross between Giza75 and Giza81.Suvin as Indian variety was developed from the hybridization between Sujata and Vincent.

F_2 generation with original parents were grown in no replicated rows 4.0 meter long with 40 cm hill space, while row to row width was kept 65 cm apart. One plant was left per hill at thinning time. Self pollination was practiced for all F_2 plants. Selfed as well as open pollinated bolls/plant of 300guarded plants were picked up separately and the total seed cotton yield/plant was ginned and lint yield /plant, bolls/plant, seeds/boll, lint/seed, boll weight, seed index and lint percentage were determined.

Using 5% selection intensity the plants having the highest performance in each selection procedures were saved. These gave a total of 53 F_3 selected progenies (fifteen superior progenies from each selection procedure).

In 2006 season, part of selfed seeds of 53 selected progenies were evaluated with a random sample of bulked seed of F_3 generation in a randomized complete blocks design with three replicates. Experimental plot was of single row as carried in 2005.

The 53 progenies were ranked using fourteen selection procedures. The five superior progenies of each selection procedures were selected using 9.4% selection intensity. In 2007 season, selfed seeds of selected progenies (18 progenies) were evaluated with a random sample of bulked seed of F_4 generation in a randomized complete blocks design with three replicates. Experimental plot was lay out as same as carried out in 2006.The planting dates were April 14,10and 17 in 2005, 2006 and 2007, respectively.
Selection procedures were as follows:

I_{w12} = Selection index involving lint yield/plant, bolls/plant and seeds/boll.
I_{w13} = Selection index involving lint yield/plant, bolls/plant and lint/seed.
I_{w23} = Selection index involving lint yield/plant, seeds/boll and lint/seed.
I_{123} = Selection index involving bolls/plant, seeds/boll and lint/seed.
I_{w1} = Selection index involving lint yield/plant and bolls/plant.
I_{w2} = Selection index involving lint yield/plant and seeds/boll.
I_{w3} = Selection index involving lint yield/plant and lint/seed.

I_{12} = Selection index involving bolls/plant and seeds/boll.
I_{13} = Selection index involving bolls/plant and lint/seed.
I_{23} = Selection index involving seeds/boll and lint/seed.
$Ped._w$ = Pedigree selection for lint yield/plant.
$Ped._1$ = Pedigree selection for bolls/plant.
$Ped._2$ = Pedigree selection for seeds/boll.
$Ped._3$ = Pedigree selection for lint/seed.

The studied characters were: lint yield (g)/plant (X_w), bolls/plant (x_1), seeds/boll (x_2), lint (g)/seed (x_3), boll weight (g), seed index (g), lint percentage, fiber length at 2.5% span length (mm), fiber strength (g/tex), yellowness degree (+b).

Statistical and genetic analysis

Heritability in broad sense was calculated according to the following expressions.

$$h^2_b \text{ (in } F_2 \text{ generation)} = \frac{VF_2 - (VP1 + VP_2)/2}{VF_2} \times 100$$

$$h^2_b \text{ (in } F_3 \text{ and } F_4 \text{ generation)} = \frac{\sigma^2 g}{\sigma^2 p} \times 100 \quad \text{(Walker 1960)}$$

Where:

VF_2 = The phenotypic variance of the F_2 population.
VP_1 = The variance of the first parent (Giza 86).
VP_2 = The variance of the second parent (Suvin).
$\sigma^2 g$ = The genotypic variance of the F_3 and F_4 generations.
$\sigma^2 p$ = The phenotypic variance of the F_3 and F_4 generations.

The phenotypic and genotypic coefficients of variation were estimated using the formula developed by Burton (1952).

The relative importance or economic values (a_i) was calculated according to Walker (1960).

a_w (lint yield/plant)$=\overline{X}_1.\overline{X}_2.\overline{X}_3$

a_1 (bolls/plant)$=\overline{X}_2.\overline{X}_3$

a_2 (seeds/boll)$=\overline{X}_1.\overline{X}_3$

a_3 (lint/seed) $=\overline{X}_1.\overline{X}_2$

Where: X's represent the mean values of the studied characters.

The appropriate index weights (b's) were calculated from the following formula postulated by Smith (1936) and Hazel (1943):

$$(b) = (P)^{-1}.(G).(a)$$

Where:

(b)=Vector of relative index coefficients,

$(P)^{-1}$=Inverse phenotypic variance-covariance matrix,

(G)=Genotypic variance-covariance matrix and

(a)=Vector of relative economic values.

The formula suggested by Smith (1936) and Hazel (1943) was used in calculating various selection indices:

$$I=b_1x_1+b_2x_2+.....+b_nx_n$$

Predicted improvement in lint yield on the basis of an index was estimated according to the following expression:

Selection advance (ΔA) = $SD(\sum b_i.\sigma g_{iw})^{1/2}$ (Walker 1960)

Where:

SD denotes selection differential in standard units.

b_i denotes index weights for characters considered in an index.

σg_{iw} denotes genotypic covariances of the characters with yield.

Predicted genetic advance in lint yield based on pedigree selection was estimated from the following expression:

(ΔG_w) due to selection for $X_i=K.\sigma g_{wi}/\sigma p_i$ (Miller and Rawlings 1967).

Also, the predicted response in any selected and unselected character was calculated as suggested by Robinson *et al* (1951) and Walker (1960).

The realized gains was calculated as deviation of generation mean for each character from procedure mean of that character. The path coefficient analysis as formulated by Dewey and Lu (1959) was estimated.

RESULTS AND DISCUSSION

Heritability values in broad-sense, phenotypic (PCV) and genotypic (GCV) coefficients of variation, and means for all traits are presented in Table (1). With an exception for seeds/boll in the three generations and boll weight in F_2 and F_3 generations, estimates of heritability for all traits were high. In spite of the high heritability estimates recorded for most traits but these estimates are often obtained from limited material, and therefore, such parameters may be subject to large sample errors including biases arising from G x E interaction.

The observed phenotypic and genotypic coefficients of variability were larger in F_2 than those of the succeeding generations for lint yield/plant, bolls/plant, seeds/boll and lint percentage. Both PCV and GCV in F_3 generation were higher than F_4 for lint yield/plant, bolls/plant, seed

Table 1. Estimates of broad sense heritability (h^2_b), phenotypic (PCV) and genotypic (GCV) coefficients of variation, means and standard errors ($S\bar{x}$) for the ten studied characters in F_2, F_3 and F_4 generations.

Character	Generation	h^2_b	PCV %	GCV %	Mean ± $S\bar{x}$
Lint yield (g)/plant (X_w)	F_2	71.1	30.0	25.3	24.27 ± 0.42
	F_3	75.9	26.3	22.9	28.33 ± 3.66
	F_4	64.0	21.4	17.1	31.80 ± 4.08
Bolls/plant (x_1)	F_2	71.5	29.9	25.3	20.14 ± 0.35
	F_3	76.1	26.0	22.7	26.67 ± 3.39
	F_4	53.1	20.5	14.9	28.56 ± 4.01
Seeds/boll (x_2)	F_2	43.4	8.4	5.5	18.31 ± 0.09
	F_3	30.3	6.9	3.8	18.21 ± 1.05
	F_4	35.4	8.3	5.0	17.24 ± 1.16
Lint (g)/seed (x_3)	F_2	50.0	8.3	5.9	0.066 ± 0.0003
	F_3	83.3	7.2	6.6	0.059 ± 0.002
	F_4	71.0	8.6	7.2	0.065 ± 0.003
Boll weight (g)	F_2	34.4	7.6	4.5	3.27 ± 0.01
	F_3	42.8	7.1	4.7	2.77 ± 0.15
	F_4	74.3	9.4	8.1	2.93 ± 0.14
Seed index (g)	F_2	57.5	6.3	4.8	11.30 ± 0.04
	F_3	82.2	7.1	6.4	9.38 ± 0.28
	F_4	59.2	6.4	4.9	10.56 ± 0.43
Lint percentage	F_2	69.5	4.1	3.4	36.92 ± 0.09
	F_3	90.1	3.4	3.2	38.52 ± 0.41
	F_4	84.6	3.7	3.4	38.19 ± 0.55
Fiber length at 2.5% span length (mm)	F_3	89.0	5.0	4.7	30.81 ± 0.51
	F_4	87.1	5.0	4.6	30.47 ± 0.55
Fiber strength (g/tex)	F_3	74.9	5.8	5.0	34.77 ± 1.01
	F_4	68.6	6.1	5.1	35.65 ± 1.22
Yellowness degree (+b)	F_3	93.7	9.7	9.4	9.24 ± 0.22
	F_4	89.4	8.7	8.2	8.87 ± 0.25

index, fiber length at 2.5% span length and yellowness degree. This indicates that, the magnitude of the genetic variability persisted in these material was sufficient for providing rather substantial amounts of improvement through the selection of superior progenies. Similar results were obtained by Meena *et al* (2001) and El-Lawendey (2003).

Comparing means of F_4 generation with those F_3, it is apparent that the means of F_4 were higher than those of F_3 for lint yield/plant, bolls/plant, lint/seed, boll weight, seed index and fiber strength. This attributed to the efficiency of selection procedures application in this study. Similar results were obtained by Meena *et al* (1991) and Meena *et al* (2001).

Gain from selection for lint yield/plant

Predicted and realized advances from selection procedures for lint yield alone are presented in Table (2), whereas Table (3) presents data of lint components. The highest predicted genetic advance from F_2 generation was obtained with the indices I_{w2}, I_{w3} and I_{12}. Because bolls/plant, seeds/boll and lint/seed have a large direct effects and the contribution of the three

Table 2. Predicted and realized gains from the different selection procedures for improving lint yield (g)/plant in F_2, F_3 and F_4 generations.

Selection procedures	Predicted gain F_2			Realized gain F_3			D	Predicted gain F_3			Realized gain F_4			D
	i	ii%	iii%	i	ii%	iii%		i	ii%	iii%	i	ii%	iii%	
I_{w12}	10.00	41.2	93.7	10.73	38.9	100.0	-0.73	9.51	33.6	96.2	2.34	7.5	100.0	7.17
I_{w13}	9.71	40.0	91.0	10.69	38.8	99.6	-0.98	9.44	33.3	95.4	4.90	15.8	209.4	4.54
I_{w23}	12.39	51.1	116.1	10.73	38.9	100.0	1.66	13.40	47.3	135.5	2.34	7.5	100.0	11.06
I_{123}	12.56	51.8	117.7	9.99	36.2	93.1	2.57	13.40	47.3	135.5	6.63	21.3	283.3	6.77
I_{w1}	9.97	41.1	93.4	10.73	38.9	100.0	-0.76	9.51	33.6	96.2	2.34	7.5	100.0	7.17
I_{w2}	13.38	55.1	125.4	10.44	37.9	97.3	2.94	13.10	46.2	132.5	4.95	15.9	211.5	8.15
I_{w3}	13.07	53.9	122.5	10.44	37.9	97.3	2.63	12.84	45.3	129.8	4.95	15.9	211.5	7.89
I_{12}	12.91	53.2	121.0	8.56	31.0	79.8	4.35	11.50	40.6	116.3	2.76	8.9	117.9	8.74
I_{13}	12.68	52.2	118.8	9.69	35.1	90.3	2.99	12.77	45.1	129.1	2.19	7.0	93.6	10.58
I_{23}	-0.19	-0.8	-1.8	-1.91	-6.9	-17.8	1.72	7.49	26.4	75.7	-2.01	-6.5	-85.9	9.50
Ped.$_w$	10.67	44.0	100.0	10.73	38.9	100.0	-0.06	9.89	34.9	100.0	2.34	7.5	100.0	7.55
Ped.$_1$	10.18	41.9	95.4	10.04	36.4	93.6	0.14	9.73	34.3	98.4	4.07	13.1	173.9	5.66
Ped.$_2$	0.09	0.4	0.8	-0.50	-1.8	-4.7	0.59	-2.01	-7.1	-20.3	-6.17	-19.9	-263.7	4.16
Ped.$_3$	2.00	8.2	18.7	-0.94	-3.4	-8.8	2.94	3.47	12.2	35.1	-2.23	-7.2	-95.3	5.70

$\bar{F}_2 = 24.27$ $\bar{F}_3 = 28.33$ $\bar{F}_4 = 31.80$ Check mean $(F_3) = 27.57$ Check mean $(F_4) = 31.07$

(i) Predicted and realized gains as lint (g)/plant.

(ii%) Predicted and realized gains percentage as estimated from generation mean and check means, respectively.

(iii%) Predicted and realized gains as a percentage of the response to truncation pedigree selection for lint yield only.

(D) Deviations of realized gains from predicted gains are given as lint (g)/plant.

Table 3. Predicted and realized responses to selection by using fourteen different selection procedures which estimated from F_2, F_3 and F_4 means for bolls/plant, seeds/boll and lint/seed.

Selection procedures	Bolls/plant (x_1)								Seeds/boll (x_2)								Lint (g)/seed (x_3)							
	Predicted response F_2		Realized response F_3		Predicted response F_3		Realized response F_4		Predicted response F_2		Realized response F_3		Predicted response F_3		Realized response F_4		Predicted response F_2		Realized response F_3		Predicted response F_3		Realized response F_4	
	i	ii%	i	ii%	i	ii%	i	ii%	i	ii%	i	ii%	i	ii%	i	ii%	i	ii%	i	ii%	i	ii%	i	ii%
I_{w12}	7.14	35.5	10.08	36.3	8.73	32.7	4.02	15.3	-0.001	-0.01	-0.42	-2.3	-0.02	-0.11	-1.00	-5.7	0.0000	0.00	0.0010	1.8	0.000004	0.007	0.001	1.5
I_{w13}	7.18	35.7	9.33	33.6	8.11	30.4	5.36	20.5	-0.007	-0.04	-0.16	-0.9	-0.02	-0.11	-0.55	-3.1	0.0000	0.00	0.0014	2.5	0.00001	0.017	0.001	1.5
I_{w23}	8.87	44.0	10.08	36.3	12.08	45.3	4.02	15.3	-0.001	-0.01	-0.42	-2.3	-0.07	-0.38	-1.00	-5.7	0.0000	0.00	0.0010	1.8	0.00002	0.034	0.001	1.5
I_{123}	8.00	39.7	9.61	34.6	12.21	45.8	6.44	24.6	-0.040	-0.22	-0.95	-5.3	-0.18	-0.99	0.01	0.1	0.0000	0.00	0.0022	3.9	0.00004	0.068	0.000	0.0
I_{w1}	7.07	35.1	10.08	36.3	8.60	32.2	4.02	15.3	0.000	0.00	-0.42	-2.3	-0.05	-0.27	-1.00	-5.7	0.0000	0.00	0.0010	1.8	0.00001	0.017	0.001	1.5
I_{w2}	9.57	47.5	9.51	34.2	11.51	43.2	5.29	20.2	-0.001	-0.01	-0.81	-4.5	-0.14	-0.77	-0.38	-2.2	0.0000	0.00	0.0027	4.8	0.0`0004	0.068	0.001	1.5
I_{w3}	8.92	44.3	9.51	34.2	11.25	42.2	5.29	20.2	0.000	0.00	-0.81	-4.5	-0.13	-0.71	-0.38	-2.2	0.0000	0.00	0.0027	4.8	0.00004	0.068	0.001	1.5
I_{12}	10.18	50.5	8.35	30.0	10.84	40.6	3.36	12.8	-0.019	-0.10	-0.22	-1.2	-0.03	-0.16	-0.09	-0.5	0.0000	0.00	-0.0002	-0.4	0.000001	0.007	-0.001	-1.5
I_{13}	10.38	51.5	9.90	35.6	12.21	45.8	3.57	13.6	-0.204	-1.11	-1.21	-6.7	-0.24	-1.32	-0.67	-3.8	0.0000	0.00	0.0020	3.6	0.00004	0.068	0.000	0.0
I_{23}	-2.79	-13.9	-4.79	-17.2	-10.19	-38.2	-2.78	-10.6	0.751	4.10	0.42	2.3	0.66	3.62	-0.47	-2.7	0.0002	0.30	0.0062	11.1	0.0021	3.559	0.004	5.9
Ped. $_w$	8.42	41.8	10.08	36.3	9.05	33.9	4.02	15.3	0.020	0.11	-0.42	-2.3	-0.34	-1.87	-1.00	-5.7	0.0015	2.27	0.0010	1.8	0.0020	3.390	0.001	1.5
Ped.$_1$	8.87	44.0	10.36	37.3	9.24	34.6	5.10	19.5	-0.351	-1.92	-1.20	-6.7	-0.34	-1.87	-0.44	-2.5	0.0018	2.73	0.0018	3.2	0.0010	1.695	0.000	0.0
Ped.$_2$	-1.38	-6.9	-2.37	-8.5	-1.87	-7.0	-5.02	-19.2	1.369	7.48	2.55	14.2	0.67	3.68	0.10	0.6	-0.0025	-3.79	-0.0030	-5.4	-0.002	-3.390	-0.001	-1.5
Ped.$_3$	0.51	2.5	-2.50	-9.0	1.70	6.4	-2.34	-8.9	-0.690	-3.77	-0.80	-4.4	-0.60	-3.29	-0.95	-5.4	0.0056	8.48	0.0068	12.1	0.0060	10.169	0.004	5.9
	$\bar{F}_2 = 20.14$								$\bar{F}_2 = 18.31$								$\bar{F}_2 = 0.066$							
	$\bar{F}_3 = 26.67$		Check mean (F_3) = 27.80						$\bar{F}_3 = 18.21$		Check mean (F_3) = 18.0						$\bar{F}_3 = 0.059$		Check mean (F_3) = 0.056					
	$\bar{F}_4 = 28.56$		Check mean (F_4) = 26.21						$\bar{F}_4 = 17.24$		Check mean (F_4) = 17.56						$\bar{F}_4 = 0.065$		Check mean (F_4) = 0.068					

characters to lint yield/plant was responsible for 86.5% of the total variation (Tables 4 and 5). On the other hand, the lowest predicted genetic advances for lint yield were obtained when selecting for seeds/boll with lint seed (I_{23}) due to negative indirect effects on lint yield/plant through the interaction between two characters.

The highest realized genetic advance from F_3 generation for lint yield occurred when selecting for I_{w12}, I_{w23}, I_{w1} and Ped.$_w$. Estimates of the direct effects on lint yield through bolls/plant (0.981), seeds/boll (0.234) and lint/seed (0.246) indicated that these three characters were the most effective yield contributing (Table 3). Similar conclusions reported were reported by Badr *et al* (1999).

Deviations of the realized advance from the predicted of lint yield/plant using different selection procedures from F_2 to F_3 generations are presented in Table (2). These deviations were positive and low for most indices. The close agreement between predicted and realized responses to Ped.$_w$ and Ped.$_2$ may be due to the non additive effects which were relatively of minor importance and the additive genetic effects would appear to be predominant.

Maximum predicted and realized advances from F_3 and F_4 generations, respectively for lint yield were achieved when selecting for bolls/plant with seeds/boll and lint/seed (I_{123}). These main attributes of lint yield were responsible for about 99.8% and 99.2% in F_3 and F_4 generations, respectively (Table 5). The lowest predicted and realized gains for lint yield arose with pedigree selection for seeds/boll (Ped.$_2$). This may be attributed to low value of heritability of seeds/boll in the three studied generations (Table 1).

Deviations of the realized advance from the predicted of lint yield from F_3 to F_4 generations (Table 2) were positive and high for all selection procedures. These results were expected because planting date of F_4 generation was later than those of F_3 generation.

Generally, realized relative efficiencies for different selection procedures for improving lint yield/plant as estimated from F_3 and F_4 generations are shown in Table (2), Figures 1 and 2. The indices I_{w12}, I_{w23} and I_{w1} were equally efficient with pedigree selection for lint yield/plant (Ped.$_w$) in F_3 generation. The realized efficiencies relative to selection for Ped.$_w$ were 283.3% for I_{123}, 211.5% for I_{w2}, 211.5% for I_{w3} and 209.4% for I_{w13} in F_4 generation. This study demonstrates that the efficacy of a selection procedure such as I_{123} is limited by the contribution of total direct and indirect effects and available genetic variability in a population. These results are in good agreement with those obtained by El-Kilany (1986), Younis (1999) and El-Lawendey (2003).

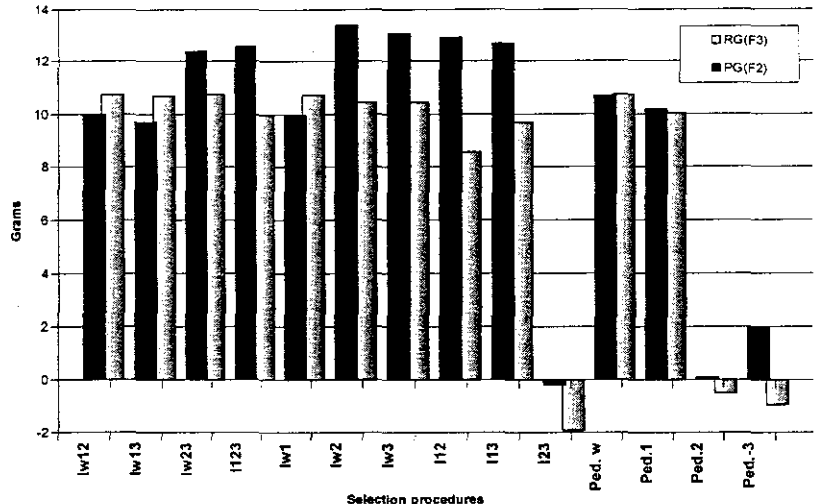

Fig.1.Predicted and realized gains for lint yield from F2 and F3 generations, respectively.

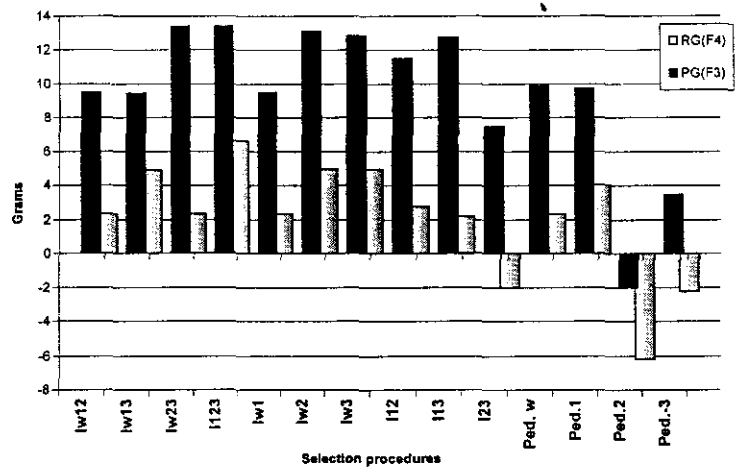

Fig.2.Predicted and realized gains for lint yield from F3 and F4 generations, respectively.

Table 4. The direct (in brackets) and indirect effects on lint yield/plant through bolls/plant, seeds/boll and lint/seed in F_2, F_3 and F_4 generations.

Character	Generation	Bolls/plant	Seeds/boll	Lint/seed	Correlation coefficient with yield
Bolls/plant	F_2	(0.985)	-0.045	0.010	0.951**
	F_3	(0.981)	-0.061	0.043	0.963**
	F_4	(0.931)	0.036	-0.087	0.880**
Seeds/boll	F_2	-0.159	(0.278)	-0.098	0.021
	F_3	-0.258	(0.234)	-0.098	-0.122
	F_4	0.087	(0.388)	-0.143	0.333
Lint/seed	F_2	0.040	-0.109	(0.251)	0.183**
	F_3	0.173	-0.093	(0.246)	0.326*
	F_4	-0.194	-0.132	(0.420)	0.094

* and ** significant at 0.05 and 0.01 levels of probability, respectively.

Table 5. Components (direct and joint effect) of bolls/plant, seeds/boll and lint/seed to lint yield/plant in F_2, F_3 and F_4 generations.

Sources	F_2 generation		F_3 generation		F_4 generation	
	CD	%	CD	%	CD	%
Bolls/plant (B/P)	0.971	75.54	0.963	72.24	0.866	56.02
Seeds/boll (S/B)	0.077	6.01	0.055	4.10	0.151	9.74
Lint/seed (L/S)	0.063	4.91	0.061	4.55	0.176	11.38
(B/P) x (S/B)	-0.088	6.86	-0.121	9.05	0.068	4.39
(B/P) x (L/S)	0.020	1.58	0.085	6.38	-0.163	10.51
(S/B) x (L/S)	-0.055	4.25	-0.046	3.43	-0.111	7.16
Residual	0.012	0.85	0.003	0.25	0.013	0.80

CD refer to coefficient of determination % refer to percentage contributed

Gain from selection for selected bolls/plants, seeds/boll and lint/seed

Predicted and realized responses to selection obtained from using different selection procedures for bolls/plant, seeds/boll and lint/seed are given in Table (5). The indices I_{13} and Ped.$_1$ gave high values of predicted and realized advances for bolls/plant from F_2 and F_3 generations, respectively. The index involving bolls/plant, seeds/boll and lint/seed (I_{123}) showed the highest predicted and realized responses from F_3 and F_4 generations, respectively for bolls/plant. There was close agreement between lint yield/plant and bolls/plant for predicted and realized gains. These agreements suggest that selection for increased lint yield/plant will result in an increase in the bolls/plant. Pedigree selection for seeds/boll (Ped.$_2$) gave high values of gains for seeds/boll in all studied generations. The highest gains from selection for lint/seed were obtained by using Ped.$_3$. Therefore, pedigree selection for bolls/plant, seeds/boll and lint/seed are recommended in itself improvement. The large discrepancies between

predicted and realized gains for bolls/plant, seeds/boll and lint/seed were expected because genotypic variances and covariances used to calculate predicted gains were likely biased by certain genotypic x environment interaction. Similar results were obtained by Singh *et al* (1986), Younis (1999) and El-Lawendey (2003).

Gain from selection for unselected boll weight, seed index and lint percentage

Realized gains exceeded predicted gains from selection for boll weight in F_3 and F_2 generations, respectively. On the other hand, predicted gains exceeded realized gains from most selection procedures for boll weight in F_3 and F_4 generations, respectively. This shifting may be due to the shifting in heritabilities (Table 1) and correlation coefficients with lint yield (Tables 7 and 8) from F_2 to F_4 generations. The highest predicted advances for boll weight from F_2 and F_3 generations were obtained by using $Ped._2$ and I_{23}, respectively. The index I_{123} gave high value of realized gain for boll weight in F_4 generation. This may be interpreted on the basis of the kind of association between lint yield/plant, bolls/plant and boll weight for index I_{123}.

Data in Table (6) indicated that the highest predicted gains were achieved for seed index by using $Ped._3$ and I_{23} from F_2 and F_3 generations, respectively. The index I_{123} was superior to all selection procedures in amount of realized gain for seed index. There is a clear indication that index I_{123} could accomplish increases of lint yield/plant, bolls/plant, boll weight and seed index in F_4 generation.

In the three studied generations, the selection index involving seeds/boll and lint /seed (I_{23}) and pedigree selection for lint/seed ($Ped._3$) were the most effective in improving lint percentage in comparison with other selection procedures. This may be attributed to positive correlation of lint/seed with lint percentage. Similar results were obtained by Culp and Harrell (1975).

Table 6. Predicted and realized responses to selection by using fourteen different selection procedures which estimated from F_2, F_3 and F_4 means for boll weight, seed index and lint percentage traits.

Selection procedures	Boll weight (g)								Seed index (g)								Lint percentage							
	Predicted response F_2		Realized response F_3		Predicted response F_3		Realized response F_4		Predicted response F_2		Realized response F_3		Predicted response F_3		Realized response F_4		Predicted response F_2		Realized response F_3		Predicted response F_3		Realized response F_4	
	i	ii%	i	ii%	i	ii%	i	ii%	i	ii%	i	ii%	i	ii%	i	ii%	i	ii%	i	ii%	i	ii%	i	ii%
I_{w12}	0.001	0.03	0.01	0.4	-0.003	-0.11	-0.16	-5.1	-0.001	-0.01	0.30	3.3	0.029	0.31	-0.01	-0.1	0.06	0.16	-0.19	-0.5	-0.03	-0.08	0.19	0.5
I_{w13}	-0.001	-0.03	0.09	3.4	0.004	0.14	-0.04	-1.3	0.000	0.00	0.48	5.2	0.056	0.60	0.23	2.1	0.06	0.16	-0.43	-1.1	-0.05	-0.13	-0.26	-0.7
I_{w23}	0.000	0.00	0.01	0.4	0.001	0.04	-0.16	-5.1	-0.002	-0.02	0.30	3.3	0.055	0.59	-0.01	-0.1	0.14	0.38	-0.19	-0.5	-0.03	-0.08	0.19	0.5
I_{123}	-0.002	-0.06	0.02	0.7	0.002	0.07	0.04	1.3	-0.003	-0.03	0.65	7.1	0.128	1.36	0.27	2.4	0.07	0.19	-0.55	-1.4	-0.07	-0.18	-0.72	-1.9
I_{w1}	0.001	0.03	0.01	0.4	0.000	0.00	-0.16	-5.1	-0.001	-0.01	0.30	3.3	0.038	0.41	-0.01	-0.1	0.09	0.24	-0.19	-0.5	-0.02	-0.05	0.19	0.5
I_{w2}	0.001	0.03	0.06	2.2	0.004	0.14	-0.01	-0.3	0.000	0.00	0.68	7.4	0.125	1.33	0.26	2.3	0.10	0.27	-0.41	-1.1	-0.06	-0.16	-0.47	-1.2
I_{w3}	0.001	0.03	0.06	2.2	0.004	0.14	-0.01	-0.3	-0.002	-0.02	0.68	7.4	0.122	1.30	0.26	2.3	0.21	0.57	-0.41	-1.1	-0.05	-0.13	-0.47	-1.2
I_{12}	-0.001	-0.03	-0.02	-0.7	-0.001	-0.04	-0.05	-1.6	-0.011	-0.10	0.04	0.4	0.007	0.07	-0.13	-1.2	-0.03	-0.08	-0.04	-0.1	-0.01	-0.03	-0.01	0.0
I_{13}	-0.007	-0.21	-0.06	-2.2	-0.005	-0.18	-0.11	-3.5	0.015	0.13	0.43	4.7	0.086	0.92	0.01	0.1	0.08	0.22	-0.09	-0.2	-0.01	-0.03	-0.04	-0.1
I_{23}	0.099	3.03	0.26	9.7	0.420	15.16	-0.03	-1.0	0.003	0.03	0.39	4.3	1.195	12.74	-0.05	-0.5	1.29	3.49	1.58	4.2	1.39	3.61	1.30	3.4
$Ped._w$	0.034	1.04	0.01	0.4	0.059	2.13	-0.16	-5.1	0.003	0.03	0.30	3.3	0.416	4.43	-0.01	-0.1	0.69	1.87	-0.19	-0.5	-0.24	-0.62	0.19	0.5
$Ped._1$	-0.050	-1.53	-0.06	-2.2	0.029	1.05	-0.08	-2.6	0.002	0.02	0.48	5.2	0.344	3.67	0.02	0.2	0.33	0.89	-0.30	-0.8	-0.43	-1.12	-0.27	-0.7
$Ped._2$	0.138	4.22	0.21	7.9	0.001	0.04	-0.06	-1.9	-0.493	-4.36	-0.61	-6.7	-0.331	-3.53	-0.23	-2.1	0.11	0.30	0.48	1.3	0.03	0.08	-0.15	-0.4
$Ped._3$	0.030	0.92	0.12	4.5	0.130	4.69	-0.05	-1.6	0.314	2.78	0.61	6.7	0.608	6.48	0.25	2.3	1.12	3.03	1.21	3.2	0.82	2.13	0.88	2.3
	$\bar{F}_2 = 3.27$ $\bar{F}_3 = 2.77$ $\bar{F}_4 = 2.93$		Check mean (F_3) = 2.67 Check mean (F_4) = 3.13						$\bar{F}_2 = 11.30$ $\bar{F}_3 = 9.38$ $\bar{F}_4 = 10.56$		Check mean (F_3) = 9.17 Check mean (F_4) = 11.07						$\bar{F}_2 = 36.92$ $\bar{F}_3 = 38.52$ $\bar{F}_4 = 38.19$		Check mean (F_3) = 38.00 Check mean (F_4) = 37.90					

Table 7. The direct (in brackets) and indirect effects on lint yield/plant through boll weight, seed index and lint percentage in F_2, F_3 and F_4 generations.

Character	Generation	Boll weight	Seed index	Lint percentage	Correlation coefficient with yield
Boll weight	F_2	(0.070)	0.009	0.016	0.096
	F_3	(0.047)	0.202	-0.006	0.243
	F_4	(0.488)	0.005	-0.002	0.491*
Seed index	F_2	0.018	(0.037)	-0.044	0.011
	F_3	0.024	(0.398)	-0.032	0.390**
	F_4	0.276	(0.009)	-0.006	0.278
Lint percentage	F_2	0.005	-0.008	(0.210)	0.208**
	F_3	-0.003	-0.151	(0.085)	-0.069
	F_4	0.009	0.001	(-0.088)	-0.079

* and ** significant at 0.05 and 0.01 levels of probability, respectively.

Table 8. Components (direct and joint effect) of boll weight, seed index and lint percentage to lint yield/plant in F_2, F_3 and F_4 generations.

Sources	F_2 generation		F_3 generation		F_4 generation	
	CD	%	CD	%	CD	%
Boll weight (BW)	0.005	0.49	0.002	0.21	0.238	23.71
Seed index (SI)	0.001	0.13	0.159	15.08	0.0001	0.01
Lint percentage (L%)	0.004	4.39	0.007	0.69	0.008	0.78
(BW) x (SI)	0.001	0.13	0.019	1.80	0.005	0.47
(BW) x (L%)	0.002	0.23	-0.001	0.06	-0.002	0.15
(SI) x (L%)	-0.003	0.32	-0.026	2.43	-0.0001	0.01
Residual	0.99	94.31	0.84	79.73	0.751	74.87

CD refer to coefficient of determination % refer to percentage contributed

Gain from selection for fiber properties

Predicted and realized gains of fiber properties from fourteen different selection procedures are presented in Table (9). The highest predicted gains for fiber length at 2.5% span length occurred when selecting for seeds/boll and lint/seed (I_{23}) and pedigree selection for lint/seed ($Ped._3$). Tables (10) and (11) showed that the direct and indirect effects of lint yield/plant from fiber length at 2.5% span length were not sizable in F_3 generation. The pedigree selection for lint/seed ($Ped._3$) and I_{wl3} exhibited the highest realized gains of 4.1% and 2.6%, respectively for fiber length at 2.5% span length relative to F_4 check mean. Tables (10) and (11) indicated that the direct effect of fiber length at 2.5% span length was positive and sizable to lint yield/plant in F_4 generation.

Concerning fiber strength, Tables (10) and (11) cleared that the direct effect was low in magnitude in F_3 generation. On the other hand, the direct effect and relative importance of fiber strength were high in

Table 9. **Predicted and realized responses to selection by using fourteen different selection procedures which estimated from F_3 and F_4 means for fiber properties.**

Selection procedures	Fiber length at 2.5% span length (mm)				Fiber strength (g/tex)				Yellowness degree (+b)			
	Predicted response F_3		Realized response F_4		Predicted response F_3		Realized response F_4		Predicted response F_3		Realized response F_4	
	i	ii%	i	ii%	i	ii%	i	ii%	i	ii%	i	ii%
I_{w12}	-0.02	-0.06	0.45	1.5	0.04	0.12	1.56	4.4	-0.07	-0.76	-0.06	-0.7
I_{w13}	-0.03	-0.10	0.78	2.6	-0.07	-0.20	1.97	5.6	-0.07	-0.76	-0.15	-1.6
I_{w23}	-0.02	-0.06	0.45	1.5	0.07	0.20	1.56	4.4	-0.10	-1.08	-0.06	-0.7
I_{123}	-0.01	-0.03	0.18	0.6	-0.06	-0.17	2.21	6.3	-0.04	-0.43	0.14	1.5
I_{w1}	-0.01	-0.03	0.45	1.5	0.05	0.14	1.56	4.4	-0.07	-0.76	-0.06	-0.7
I_{w2}	-0.02	-0.06	0.12	0.4	-0.03	-0.09	1.59	4.5	-0.09	-0.97	-0.04	-0.4
I_{w3}	-0.01	-0.03	0.12	0.4	-0.02	-0.06	1.59	4.5	-0.09	-0.97	-0.04	-0.4
I_{12}	-0.05	-0.16	-0.28	-0.9	-0.07	-0.20	0.88	2.5	-0.07	-0.76	-0.19	-2.1
I_{13}	-0.04	-0.13	-0.02	-0.1	0.02	0.06	1.24	3.5	-0.08	-0.87	-0.02	-0.2
I_{23}	1.23	3.99	0.72	2.4	-1.58	-4.54	-2.38	-6.7	-0.28	-3.03	0.06	0.7
$Ped._w$	-0.03	-0.10	0.45	1.5	0.51	1.47	1.56	4.4	-0.50	-5.41	-0.06	-0.7
$Ped._1$	-0.23	-0.75	-0.15	-0.5	0.52	1.50	1.80	5.1	-0.45	-4.87	0.22	2.4
$Ped._2$	0.14	0.45	-0.74	-2.4	-0.55	-1.58	-0.52	-1.5	0.01	0.11	0.40	4.4
$Ped._3$	0.58	1.88	1.25	4.1	0.52	1.50	-0.93	-2.6	-0.18	-1.95	-0.36	-4.0
	$\overline{F}_3 = 30.81$				$\overline{F}_3 = 34.77$				$\overline{F}_3 = 9.24$			
	$\overline{F}_4 = 30.47$				$\overline{F}_4 = 35.65$				$\overline{F}_4 = 8.87$			
	Check mean (F_4) = 30.50				Check mean (F_4) = 35.30				Check mean (F_4) = 9.11			

Table 10. The direct (in brackets) and indirect effects on lint yield/plant through fiber properties in F_3 and F_4 generations.

Character	Generation	Fiber length at 2.5% span length	Fiber strength (g/tex)	Yellowness degree (+b)	Correlation coefficient with yield
Fiber length at 2.5% span length	F_3	(0.010)	-0.014	-0.007	-0.010
	F_4	(0.219)	0.011	-0.023	0.207
Fiber strength (g/tex)	F_3	-0.001	(0.136)	-0.013	0.122
	F_4	0.005	(0.444)	0.001	0.450
Yellowness degree (+b)	F_3	0.000	0.005	(-0.315)	-0.309*
	F_4	-0.071	0.005	(0.072)	0.006

* and ** significant at 0.05 and 0.01 levels of probability, respectively.

Table 11. Components (direct and joint effect) of fiber properties to lint yield/plant in F_3 and F_4 generations.

Sources	F_3 generation		F_4 generation	
	CD	%	CD	%
Fiber length at 2.5% span length (2.5% SL)	0.0001	0.011	0.048	4.706
Fiber strength (g/tex) (S (g/t))	0.0184	1.826	0.197	19.291
Yellowness degree (+b)	0.0990	9.825	0.005	0.503
(2.5% SL) x [S (g/t)]	-0.0003	0.028	0.005	0.476
(2.5% SL) x (+b)	-0.0001	0.014	-0.010	0.997
[S(g/t)] x (+b)	-0.0034	0.339	0.001	0.075
Residual	0.8863	87.957	0.754	73.952

CD refer to coefficient of determination % refer to percentage contributed

magnitude and exceeded the other fiber traits in F_4 generation. Thus, there is disagreement between predicted and realized gains in fiber strength when using the various models of selection procedures. However, pedigree selection for bolls/plant ($Ped._1$) and lint/seed ($Ped._3$) showed the highest predicted gains for fiber strength. While the indices I_{w13} and I_{123} exhibited the highest realized gains.

Regarding yellowness degree, the path analysis affected after the first cycle since, the negative correlations among lint yield and yellowness degree in F_3 generation changed to positive in F_4 generation (Table 10). Although there are differences between the predicted and realized gain from selection, the trends for the various procedures are similar. Pedigree selection for lint yield or bolls/plant gave low values (desirable values) of predicted gains. While the indices $Ped._3$ and I_{12} showed the lowest realized gains. Similar results were recorded by Smith and Coyle (1997) and Badr *et al* (1999).

Finally, maximum gains for lint yield/plant were changed from generation to generation when applying of selection indices. However, selection index on the basis of bolls/plant and lint/seed and/or seeds/boll, with lint yield/plant would appear to be most effective for the improvement of lint yield and some economic traits. Also, pedigree selection for the traits; bolls/plant, seeds/boll and lint/seed are recommended in itself improvement only.

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استخدام أربع عشر طريقة للانتخاب لتقييم التحسين الوراثي المتوقع والفعلي لهجين القطن جيزة 86x سوفين

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يهدف هذا البحث إلى تقدير التحسين الوراثى المتوقع بالانتخاب والتحسين الفعلى لمحصول الشعر والتجاوب المتلازم لمكونات المحصول وصفات التيلة. ومقارنة الكفاءة النسبية لطرق الانتخاب المستخدمة ، وتأثير طرق الانتخاب المختلفة على معامل المرور.

ولتحقيق ذلك تم استخدام الجيل الثاني والثالث والرابع لعشيرة من القطن (جيزة 86 × سوفين) وتم تطبيق طريقتين للانتخاب هما أدلة الانتخاب (عشرة أدلة) وطريقة النسب لأربع صفات: محصول الشعر/نبات ، عدد اللوز/نبات ، عدد البذور/لوزة ووزن الشعر/بذرة).وأظهرت النتائج ما يلي:

1- أعطت متوسطات الجيل الرابع قيما أعلى من الجيل الثالث لصفات محصول الشعر/نبات ، عدد اللوز/نبات ، وزن الشعر/بذرة ، وزن اللوزة ، معامل البذرة والمتانة (جم/تكس).

2- أوضحت الفروق بين التحسين الفعلي والمتوقع لصفة محصول الشعر/نبات قيما عالية وموجبة لكل طرق الانتخاب من الجيل الثالث إلى الجيل الرابع.

3- كان ترتيب الكفاءة النسبية الفعلية على أساس طريقة النسب لمحصول الشعر/نبات في الجيل الرابع كما يلي283.3% لدليل الانتخاب المتضمن عدد اللوز/نبات ، عدد البذور/لوزة ووزن الشعر/بذرة (I_{123}) ثم 211.5% لدليلي الانتخاب المتضمنين محصول الشعر مع عدد البذور/لوزة (I_{w2}) أو وزن الشعر/بذرة (I_{w3}) ثم 209.4% لدليل الانتخاب المتضمن محصول الشعر مع عدد اللوز/نبات ووزن الشعر/بذرة (I_{w13}).

4- أظهر دليل الانتخاب I_{123} قيما عالية للتحسين لصفات محصول الشعر/نبات ، عدد اللوز/نبات ، وزن اللوزة ، معامل البذرة والمتانة (جم/تكس).

5- أوضحت النتائج أن طريقة النسب أعطت تحسينا للصفة المتضمنة لها.

6- أظهرت طريقة النسب لوزن الشعر/بذرة ($Ped._3$) قيما عالية لتحسين طول التيلة عند 2.5% وقيما منخفضة ومرغوبة لدرجة الاصفرار (b+).

7- لوحظ أن معامل المرور لبعض مكونات المحصول في كمية محصول الشعر قد تغير من الجيل الثاني إلى الجيل الرابع ويرجع ذلك إلى كفاءة طرق الانتخاب المستخدمة في هذه الدراسة.

8- يمكن لمربي القطن الاستفادة من محصلة نتائج هذه الدراسة وخاصة بعد التطور الهائل في مجالات استخدام الحاسب الآلي من استخدام أدلة الانتخاب لتحسين محصول القطن الشعر ومكوناته معا.

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