Egypt. J. Plant Breed. 15 (4):125 – 144 (2011)

DEVELOPING NEW HIGH OIL MAIZE POPULATIONS *VIA* ONE CYCLE OF S_1 RECURRENT SELECTION

A.M.M. Al-Naggar[1], M.M.M. Atta[1] and H.T.O. Hassan[2]

1- Department of Agronomy, Faculty of Agriculture, Cairo University, Giza, Egypt.
2- Maize Res. Dept., Fine Seeds International, S.A.D., Egypt.

ABSTRACT

Developing high oil maize (HOM) populations is a prerequisite for extracting suitable inbreds to developing HOM hybrids. In the present study, six new HOM populations were developed; three from Pop-59 and three from Loc-Pop populations via one cycle of S_1 recurrent selection for high oil content (OC%), high grain yield (GYPP) and high oil yield (OYPP) per plant. The resulted 6 populations along with the source populations Pop-59 and Loc-Pop were evaluated under 4 locations, representing lower, middle and higher Egypt. Actual progress in grain OC%, GYPP and OYPP was 1.2%, 37.39 g and 1.9 g for Pop-59-HOC, Pop-59-HGY and Pop-59-HOY and 1.9%, 55.9 g and 3.0 g for Loc-Pop-HOC, Loc-Pop-HGY and Loc-Pop-HOY, respectively. Estimates of actual progress were much lower than predicted, suggesting overestimation of heritability because the total genetic variance instead of additive variance was used. Selection for OYPP was associated with a significant increase of GYPP, grain carbohydrate content (CC%), OC% and 100-kernel weight, but with a significant decrease in protein content (PC%). Selection for OC% was associated with a significant decrease in GYPP, kernels/plant, and CC% but with a significant increase in PC%.

Key words: ***Maize, High oil corn, S_1 recurrent selection, Population improvement, Oil content, Grain yield, Oil yield.***

INTRODUCTION

Egypt is suffering from a great shortage in edible oils. Maize crop is qualified to help in narrowing this gap of edible oil as a secondary product besides its primary purpose as a cereal crop. In corn grain, a typical hybrid cultivar contains approximately 4% oil, 9% protein, 73% starch, and 14% other constituents (mostly fiber) However, oil content of high oil maize (HOM) grain exceeds 6%. The value of high-oil maize (HOM) is reflected in higher oil, amino acid and protein contents than normal maize (Han *et al* 1987 and Song 2001). Given the high levels of unsaturated fatty acids, especially oleic (18:1) in HOM or including it in the diet would have positive health effects. Using HOM grain not only improves the food-energy utilization rate but also reduces the amount of supplemental fats needed in livestock feeds (Goldman *et al* 1994).

Grain quality is an important objective in corn breeding (Mazur *et al* 1999 and Wang and Larkins 2001). Using traditional breeding methods during the past 100 or more years, many HOM populations and hybrid cultivars have been developed (Alexander *et al* 1967, Miller *et al* 1981, Dudley and Lambert 1992 and 2004, Song *et al* 1999, Lambert *et al* 2004, Moose *et al* 2004 and Song and Chen 2004). The Illinois long-term selection experiment is a classic illustration of efficiency of selection for chemical composition in the corn kernel (Dudley and Lambert 2004). After 104 generations mean oil concentration in "Illinois High Oil" (IHO) strain was 21.82%, with no apparent reduction in selection response. Before selection, the initial population contained 4.69% oil which is similar to current commercial hybrids. Getschman and Hallauer (1991), El-Agamy *et al* (1992) and Mahmoud *et al* (1999) reported that selection based on S_1 progeny performance is effective for utilizing additive genetic effects and presents an opportunity for selection against major deleterious recessive genes that become homozygous with inbreeding.

In the present study, one cycle of S_1 recurrent selection for oil content, grain yield and oil yield, was practiced in two HOM populations and six new improved maize populations were developed. The objectives were: (1) to evaluate the six new-developed HOM populations in comparison with the original ones, (2) to estimate the actual *vs* predicted progress in oil content, grain yield and oil yield traits from one cycle of S_1 recurrent selection, (3) to determine the associated changes in the non-selected traits and (4) to calculate trait interrelationships between pairs of grain quality and yield traits.

MATERIALS AND METHODS

Breeding material

Two yellow corn (*Zea mays* L.) populations, *i.e.* Pop-59 and Pop Loc-Pop were used in this study as source populations for practicing one cycle of S_1 recurrent selection for high oil content, high grain yield and high oil yield. These populations were kindly provided by the Agricultural Research Center (ARC). One of these populations was imported from Thailand and the other was a local population of high oil content and collected from farmers of Aga District, Dakahlia, Egypt. Both populations were considered high oil maize (HOM) germplasm since oil content in their grains is more than 6%. The name and history of development of these populations are presented in Table (1).

Table 1. Name and history of development of the populations used in this study.

Population name	History of development
Pop-59	Exotic high oil maize (HOM) population introduced from Thailand, by ARC, as HOM germplasm.
Loc-Pop	A local HOM open-pollinated population collected from Aga District, Dakahliya Governorate, Egypt and had undergone only one cycle of recurrent selection for oil content and grain yield by ARC.

Developing the S_1 progenies

In the late 2006 summer season, seeds of the populations, Pop-59 and Loc-Pop, were sown at the 15th of July under normal cultural conditions in two isolated blocks at Egaseed Agric. Res. Station, Bani Hedair, Bani Sweif Governorate. More than one thousands vigorous and disease-free plants in each population were self-pollinated. The best 144 selfed ears based on the desirable ear characteristics representing each population were chosen. Thus, two groups of S_1 progenies were made; each group consisted of 144 S_1's as follows: (1) Group 1: consisted of 144 S_1's from Pop-59 and (2) Group 2: consisted of 144 S_1's from Loc-Pop. Ears of the two selected groups were separately shelled and their respective seeds were preserved for progeny evaluation in the next season.

Progeny evaluation of S_1's

In the 2007 summer season, seeds of 144 S_1 progenies of each group were separately sown for evaluation at Egaseed Agric. Res. Sta., on the 15th of May in two-row plots. Rows were 5 m long and 0.7m wide. *i.e.* plot size = 7.0 m^2. Sowing was made in hills spaced 25 cm along the row and plants were thinned to one per hill before the first irrigation. A separate lattice design (12 x 12) with three replications was used for evaluating each group of S_1 progenies for grain yield characters. The S_1 progenies were also sown in two additional replications, for seed production by artificial sib-pollination to prevent possible pollen effects (Xenia) of other entries on grain oil content, to allow an accurate evaluation of oil content in these S_1 progenies according to Misevic and Alexander (1989), Lambert *et al* (1998) and Soliman *et al* (2007). Recommended cultural practices were applied for the six replications of each experiment. Selection was practiced in each group of S_1's either for high grain oil content (HOC), high grain yield (HGY), and high plant oil yield (HOY). The highest 14 S_1's (about 10% of the 144 S_1's), for each of the above three traits were selected to form three sub-groups from each population selected for HOC, HGY, and HOY, making a total of six sub-groups representing the best S_1's for Pop-59-HOC, Pop-59-HGY Pop-59-HOY, Loc-Pop- HOC, Loc-Pop-HGY, and Loc-Pop-HOY.

Intercrossing among the selected S_1's

In the early summer season of 2008, the selected six sub-groups were sown separately in 14 isolated blocks for making all possible cross combinations among the S_1's of each sub-group at Fine Seeds Res. Station, Beba, Bani-Sweif Governorate. For each sub-group a blend of equal number of seeds of each 14 S_1's was sown in a separate intercrossing block for artificial sib-pollination among all plants in each block. Ears harvested from each intercrossing block were shelled and their seeds were blended to form one sub-population. Therefore, six sub-populations were obtained as follows: (1) Sub-population I (Pop-59-HOC) represents an experimental population selected for high oil content developed from Pop-59. (2) Sub-population II (Pop-59-HGY) represents an experimental population selected for high grain yield/plant developed from Pop-59. (3) Sub-population III (Pop-59-HOY) represents an experimental population selected for high oil yield/plant developed from Pop-59. (4) Sub-population IV (Loc-Pop-HOC) represents an experimental population selected for high oil content (%) developed from the Loc-Pop. (5) Sub-population V (Loc-Pop-HGY) represents an experimental population selected for high grain yield/plant developed from the Loc-Pop. (6) Sub-population VI (Loc-Pop-HOY) representing an experimental population selected for high oil yield/plant developed from the Loc-Pop.

Random-mating of selected sub-populations

In the late summer season of 2008, seeds of each of the six sub-populations were separately sown at Fine Seeds Res. Sta., Beba, in six isolated blocks (each block consisted of 20 rows). Pollen grains from several plants in the 10 rows of each sub-population were collected and used for pollinating silks of all plants of the same sub-population, to achieve random-mating among plants for one generation in order to reach genetic equilibrium. Each block was harvested separately, ears were shelled and seeds from each block were blended thoroughly. Therefore, seeds of six improved sub populations were obtained and referred to thereafter as Pop-59-HOC, Pop-59-HGY, Pop-59-HOY, Loc-Pop-HOC, Loc-Pop-HGY, and Loc-Pop-HOY.

Evaluation of selected populations

In the summer season of 2009, seeds of the above six selected sub populations and the two original populations (Pop-59 and Loc-Pop), were evaluated at four locations, *i.e.* Kom Hamada (Beheira Governorate), Ashmoon (Menofia Governorate), Beba (Bani Sweif Governorate), and Bani Ebaid (Minia Governorate). Two experiments were carried out in each location; the 1st experiment was conducted for evaluation of grain yield traits and the 2nd experiment for evaluation of grain quality traits. In each experiment a randomized complete blocks design (RCBD) was used with three replications with plot consisting of 4 rows 5m long and 0.7m wide, *i.e.* the plot area was 14 m^2. Sowing was made in hills spaced 25cm along the row and plants were thinned to one per hill before the first irrigation. Recommended cultural practices were followed for each location. For the 2nd experiment, aiming at determining grain quality traits, plants of each sub- population were self-pollinated to prevent Xenia effect of pollen from other entries on the grain quality traits.

Data recorded

Data were recorded on: (1) number of kernels/plant (KPP), (2) 100-kernel weight (100KW) in g, (3) grain yield/plant (GYPP), in g. Three samples of whole kernels were taken to represent each entry for the determination of the following grain quality traits: (4) oil content (OC%) and (5) protein content (PC%) measured on whole kernels using Zeltex ZX-800 Near-Infrared (NIR) non-destructive whole grain analyzer (manufactured by Zeltex Inc., Maryland, USA), (6) carbohydrate content (CC%) in whole kernel by Phenol Suphoric acid according to AOAC (2000); (7) oil yield/plant (OYPP) in g calculated by multiplying oil percentage by grain yield/plant on a dry matter basis and (8) protein yield/plant (PYPP) in g calculated by multiplying protein percentage by grain yield/plant on a dry matter basis.

Statistical analyses

Separate analysis of variance of RCBD design was performed at each location. Combined analysis of variance was also performed across the four locations, if the homogeneity test results (Bartlett test) were insignificant, and LSD values were calculated to compare between means according to Snedecor and Cochran (1989).

RESULTS AND DISCUSSION

Analysis of variance

Analysis of variance (Table 2) showed significant mean squares due to locations for all studied traits, except for carbohydrate content (CC%), indicating that location had a significant effect on the performance of most studied traits due to differences in climatic factors and soil properties and interactions with genotypes in different locations. Combined analysis of variance across locations (Table 2) also showed highly significant differences among the studied eight populations for all studied traits. Mean squares due to the populations x locations interaction were significant for most studied characters, indicating that populations performed differently in different locations, supporting previous results (Genter *et al* 1956, Berke and Rocheford 1995, Pixley and Bjarnason 2002, Mittelman *et al* 2003, Munamava *et el* 2004 and Al-Naggar *et al* 2010). Separate analyses of variance (Table 2) revealed significant differences among populations at all locations for all studied traits, except for 100KW and PYPP at Minia.

The degrees of freedom for populations were partitioned into its components, *i.e.* set 1, (Pop-59-HOC, Pop-59-HGY, and Pop-59-HOY), set 2 (Loc-Pop-HOC, Loc-Pop-HGY and Loc-Pop-HOY) and set 1 *vs* set 2 and their interactions with locations as presented in Table (3). Data showed that mean squares due to each of set 1 and set 2 were significant or highly significant for all studied traits, except in set 1 for 100KW, and PYPP at

Table 2. Separate and combined analyses of variance for the studied traits of eight populations in 2009 season.

SOV	Df	KPP	100KW	OC%	PC%	CC%	GYPP	OYPP	PYPP
				Mean squares					
				Beheira					
Populations (P)	7	37470.6**	58.5**	5.7**	2.0**	7.0**	7382.3**	21.1**	34.4**
Error	14	3540.4	7.1	0.1	0.03	0.03	81.9	1.0	0.7
C.V.%		9.19	9.0	3.7	1.93	0.3	4.6	6.75	5.08
				Menofia					
Populations (P)	7	41079.6**	17.0*	7.6**	5.0**	6.9**	2089.6**	7.7**	6.4**
Error	14	5140.3	5.0	0.2	0.12	0.04	98	1.03	1.17
C.V.%		11.8	8.5	4.8	3.53	0.3	6.3	8.22	7.23
				Bani Sweif					
Populations (P)	7	56136.4**	34.73**	5.63**	1.76**	5.5**	10254.1**	15.9**	74.6**
Error	14	1117.3	1.2	0.1	0.09	0.1	105.4	1.03	1.52
C.V.%		6.03	3.7	2.7	2.9	0.6	6.1	8.11	7.02
				Minia					
Populations (P)	7	35155.7*	6.7	3.2**	1.7**	5.2**	858.8**	2.7*	2.5
Error	14	13288.9	6.8	0.1	0.13	0.1	115.6	0.87	1.58
C.V.%		17.2	10	2.[illegible]	3.61	0.37	8.19	8.99	9.82
				Combined					
Locations (L)	3	62375.8**	109.7**	1.[illegible]**	7.5**	0.2	11569.5**	78.5**	107.1**
Populations (P)	7	146106.8**	71.9**	20.0**	9.2**	23.4**	15891.0**	21.3**	72.0**
P x L	21	7911.8	15.0**	0.[illegible]**	0.4**	0.4**	1564.6**	8.7**	17.3**
Error	56	5771.7	5.0	0.[illegible]	0.1	0.1	100.2	1.0	1.2
C.V.%		12.25	8.0	3.[illegible]	3.1	0.4	6.3	7.9	7.2

* and** indicate significance at 0.05 and 0.01 levels of probability, respectively.

Table 3. Partitioning population degrees of freedom among entries into set 1 (Pop-59, Pop-59-HOC, Pop-59-HGY and Pop-59-HOY) and set 2 (Loc-Pop, Loc-Pop-HOC, Loc-Pop-HGY and Loc-Pop-HOY), set 1 *vs* set 2 and interactions of sets with locations.

SOV	df	KPP	100KW	OC%	PC%	CC%	GYPP	OYPP	PYPP
				Mean squares					
				Beheira					
Set 1	3	17513.7**	70.75**	5.6**	2.2**	7.8**	1710.1**	10.5**	4.4**
Set 2	3	57438.4**	65.6**	3.3**	1.5**	4.9**	8426.9**	29.4**	41.8**
Set 1 *vs* Set 2	1	37437.9**	0.04	12.9**	2.9**	10.8**	21265.3**	28.1**	102.1**
				Menofia					
Set 1	3	44129.6**	5.0	6.1**	8.9**	9.4**	2176.4**	3.1*	2.7
Set 2	3	37825.5**	34.7**	6.5**	1.3**	2.9**	2042.2**	13.2**	11.2**
Set 1 *vs* Set 2	1	41691.9**	0.1	15.4**	4.4**	11.4**	1971.5**	5.1*	3
				Bani Sweif					
Set 1	3	27177.4**	26.3**	6.8**	1.8**	4.8**	4500.3**	4.6*	29.4**
Set 2	3	32818.4**	52.6**	3.7**	1.0**	4.5**	10610.3**	12.0**	78.1**
Set 1 *vs* Set 2	1	212967.4**	6.4*	7.9**	3.8**	10.8**	26447.1**	61.4**	199.5**
				Minia					
Set 1	3	20909.8**	0.9	2.1**	1.8**	4.0**	856.1**	3.4*	3.74
Set 2	3	46459.7**	14.5	3.4**	1.36	4.1**	746.4**	2.78	1.28
Set 1 *vs* Set 2	1	43981.4**	0.7	6.2**	2.6**	10.8**	1204.2**	0.39	2.14
				Combined analysis					
Set 1	3	92737.5**	39.1**	18.7**	12.0**	24.3**	7836.1**	13.0**	20.0**
Set 2	3	149024.4**	128.2**	14.2**	4.9**	15.7**	16726.8**	28.0**	85.4**
Set 1 *vs* Set 2	1	297461.9**	1.4	41.3**	13.7**	43.8**	37548.3**	26.1**	187.8**
Set 1 x L	9	5664.3	21.3**	0.6**	0.8**	0.7**	468.9**	2.9**	6.7**
Set 2 x L	9	5086.0	13.1*	0.9**	0.1	0.2**	1699.6**	9.8**	15.7**
Set 1 *vs* Set 2 x L	3	69395.1**	5.4	1.2**	0.3*	0.3**	13340.1**	68.4**	161.7**

* and** indicated significance at 0.05 and 0.01 levels of probability, respectively.

Menofia and Minia and in set 2 for 100KW, OYPP, and PYPP at Minia. Mean squares due to set 1 x locations and set 2 x locations interactions were significant or highly significant for all studied traits, except for KPP in set 1 or set 2 x locations and PC% in set 2 x locations interaction. Mean squares due to the orthogonal comparison, *i e* set 1 *vs* set 2 were significant for all studied traits, except 100KW at Beheira, Menofia, Minia and combined across locations, OYPP at Minia and PYPP at Menofia and Minia, indicating that set 1 entries differ significantly from those of set 2 populations for most studied traits. Mean squares due to set 1 *vs* set 2 x locations interaction were significant for all studied traits, except 100KW, indicating that differences between set 1 and set 2 may fluctuate among locations.

Performance of newly-developed populations

Means of the six improved experimental populations (Pop-59-HOC, Pop-59-HGY, Pop-59-HOY, Loc-Pop-HOC, Loc-Pop-HGY, and LOC-Pop-HOY) along with the two original populations (Pop-59 and Loc-Pop) in 2009 season at each location and across locations are presented in Table (4).

The general mean of traits across populations was different from one location to another. The highest general mean was shown by Beheira location for 4 out of 8 studied traits, namely OC%, CC%, GYPP, and OYPP (Table 4). The Beheira location is characterized by the lowest temperature (maximum temperature was 27.88°C), the highest relative humidity (RH) reaching 83.9% compared with other studied locations. On the contrary, the lowest general means across all studied populations were shown by the Minia location for GYPP, 100KW and OYPP and by Bani Sweif for OC%, CC%, KPP traits. The Minia and Bani Sweif locations are characterized by a relatively higher temperature and lower relative humidity than at the Beheira location. Moreover, soil fertilely at Beheira was better than Minia, since the preceding crop was wheat (*Triticum aestivum* L.) in Minia and a leguminous crop, namely peas (*Pisum sativum* L.) in Beheira. It is interesting to mention that the most important environmental factors that influence grain quality traits in maize (oil and protein contents) are temperature and availability of water and nitrogen in the soil (East and Jones 1920 and Letchworth and Lambert 1998). The highest grain yield per plant was shown by the improved population Loc-Pop-HGY at all locations, followed by the improved population Loc-Pop-HOY (Table 4). The two populations, Loc-Pop-HGY and Loc-Pop-HOY were developed from the local population Loc-Pop, *via* one cycle of S_1 recurrent selection, for increasing grain yield/plant and oil yield/plant, respectively.

On the other hand, the lowest grain yield per plant was exhibited by Pop-59-HOC that was developed from the exotic population (Pop-59) by selection for oil content (Table 4). The highest oil content in maize grains

Table 4. Summary of means for studied traits of maize populations developed *via* one cycle of S recurrent selection compared to the original population evaluated in 2009 season at four locations.

Location	Pop-59	Pop-59-HOC	Pop-59-HGY	Pop-59-HOY	Loc-Pop	Loc-Pop-HOC	Loc-Pop-HGY	Loc-Pop-HOY	General mean	LSD 0.05
					KPP					
Beheira	606.4	501.0	658.6	667.3	808.5	511.2	786.2	643.2	647.8	104
Menofia	562.8	395.8	659.5	646.2	712.0	544.8	775.5	565.3	607.7	126
Bani Sweif	399.1	368.3	577.7	494.9	659.9	541.9	787.7	604.2	554.2	58.5
Minia	535.5	578.9	705.7	690.4	694.4	633.7	894.6	630.4	670.5	202
Combined	525.9	461.0	650.4	624.7	718.7	557.9	811.0	610.8	620.1	124
					100KW (g)					
Beheira	24.0	32.2	34.9	27.5	2[illegible].9	26.5	34.3	33.2	29.7	4.67
Menofia	26.6	27.9	25.9	24.9	2[illegible].6	25.1	27.4	30.6	26.4	3.94
Bani Sweif	28.7	26.9	33.9	29.3	2[illegible].6	25.9	36.0	31.3	30.2	1.94
Minia	26.4	25.9	27.0	25.8	2[illegible].0	23.5	28.6	26.7	26.1	ns
Combined	26.4	28.2	30.4	26.9	2[illegible].5	25.2	31.5	30.5	28.1	3.65
					OC (%)					
Beheira	9.1	10.5	7.3	9.7	7.2	8.8	6.4	8.2	8.4	0.55
Menofia	9.4	10.6	7.3	8.3	6.5	8.4	5.6	8.7	8.1	0.68
Bani Sweif	8.7	9.9	6.3	8.6	7.0	8.7	6.0	7.1	7.8	0.39
Minia	8.5	9.5	7.5	8.9	6.5	9.0	7.2	7.7	8.1	0.39
Combined	8.9	10.1	7.1	8.9	6.3	8.7	6.3	7.9	8.1	0.49
					PC (%)					
Beheira	10.0	10.6	8.7	9.2	8.5	9.9	8.4	8.7	9.3	0.31
Menofia	10.6	12.4	8.6	9.0	8.5	10.2	9.0	9.3	9.7	0.61
Bani Sweif	11.2	11.9	10.0	10.9	10.1	11.1	9.7	10.0	10.6	0.54
Minia	9.9	11.3	9.5	9.9	9.1	10.4	8.8	9.4	9.8	0.63
Combined	10.4	11.5	9.2	9.8	9.2	10.4	9.0	9.4	9.9	0.49
					CC (%)					
Beheira	68.0	66.8	70.6	68.4	70.3	68.0	71.0	69.8	69.1	0.32
Menofia	67.7	66.1	70.0	69.5	70.3	68.4	70.6	69.5	69.0	0.36
Bani Sweif	67.8	66.8	69.8	68.5	69.3	67.8	70.5	70.2	68.9	0.66
Minia	68.5	66.9	69.9	68.1	70.2	68.0	70.7	69.8	69.0	0.45
Combined	68.0	66.6	70.1	68.6	70.1	68.1	70.7	69.8	69.0	0.43
					GYPP (g)					
Beheira	145.2	122.6	172.5	171.5	118.2	151.0	269.3	241.4	182.7	15.89
Menofia	150.0	109.2	170.8	160.0	159.2	134.2	196.7	172.5	156.6	17.38
Bani Sweif	114.6	99.0	187.3	142.2	155.6	140.3	283.3	189.6	169.0	18.02
Minia	112.5	106.7	140.8	135.8	140.8	120.8	158.3	132.5	131.0	18.87
Combined	130.6	109.4	167.9	152.4	170.9	136.6	226.9	184.0	159.8	16.35
					OYPP (g)					
Beheira	13.2	12.9	12.6	16.6	13.7	13.2	17.3	19.8	14.9	1.76
Menofia	14.0	11.6	12.4	13.3	10.3	11.3	11.1	15.0	12.4	1.78
Bani Sweif	9.9	9.8	11.8	12.2	13.7	12.3	17.0	13.6	12.5	1.78
Minia	9.6	10.1	10.6	12.1	9.[illegible]	10.8	11.3	10.2	10.5	1.64
Combined	11.7	11.1	11.9	13.5	11.7	11.9	14.2	14.7	12.6	1.63
					PYPP (g)					
Beheira	14.5	13.0	15.1	15.8	16.1	15.0	22.6	21.1	16.7	1.48
Menofia	15.8	13.5	14.7	14.4	13.8	13.7	17.7	16.1	15.0	1.90
Bani Sweif	12.8	11.8	18.8	15.4	15.7	15.6	25.6	19.0	17.3	2.16
Minia	11.1	12.0	13.3	13.5	13.3	12.6	13.9	12.5	12.8	ns
Combined	13.6	12.6	15.5	14.8	15.7	14.2	20.0	17.2	15.4	1.79

was shown by the selected population Pop-59-HOC (10.5% at Beheira, 10.6% at Menofia, 9.9% at Bani Sweif, 9.5% at Minia and 10.1% across locations). This population was developed *via* one cycle of S_1 recurrent selection for high oil content from the introduced, high oil maize (HOM) Pop-59. In the second and third rank for oil content came Pop-59-HOY and Loc-Pop-HOC (8.9 and 8.7%, respectively for combined data) with no significant difference among the two populations. On the contrary, the lowest average oil content across locations (6.3%) was exhibited by Loc-Pop-HGY developed *via* selection for high grain yield per plant from the local population (Loc-Pop).

The highest oil yield per plant was shown by Loc-Pop-HOY across locations. On the other hand, the lowest oil yield per plant and per fedan was exhibited by Pop-59-HOC. Results combined across locations indicated that the highest oil content (10.1%) was shown by population (Pop-59-HOC) which was also highest in oil yield per plant (11.1g) and in protein content (11.5%), but was lowest in protein yield per plant (12.6g), carbohydrate content (66.6%), grain yield per plant (109.4g) (Table 4). Data combined across locations showed that the highest population in grain yield (Loc-Pop-HGY) (GYPP =226.9g) was also the highest in protein yield per plant (20.0g), carbohydrate content (70.7%), KPP (38.1), 100kW (31.5g), and the second highest in oil yield per plant (14.2g), but was the lowest in oil content (6.3%) and protein content (9.0%) (Table 4). It is interesting to report that the highest population combined across locations in oil yield (Loc-Pop-HOY) (OYPP = 14.7g) was the second highest in GYPP (184.0g). Comparing the two sets of populations, *i.e.* set 1 *vs* set 2 (Table 5), indicated on average across locations, that set 1 (Pop-59 and its derived populations) is significantly higher in oil content (by 1.3%) and protein content (by 0.7%) than set 2 (Loc-Pop and its derived populations). This could be attributed to the fact that Pop-59 is introduced from Thailand and had a long history of improvement for oil content.

On the contrary, set 2 was significantly higher in grain yield per plant (by 39.6g), KPP (by 109.1 kernel), and CC (by 1.4%) than set 1. The higher oil yield and protein yield of set 1 over set 2 is due to the higher grain yield, which could be attributed to the greater adaptedness of this set of populations to local conditions than entries in set 2.

Changes in selected traits

1. Oil content

Combined data across locations (Table 6) indicated that one cycle of S_1 recurrent selection for high oil content resulted in a significant improvement in oil content of the Pop-59-HOC over its original population (Pop-59) by 1.2% (a relative improvement of 13.7%) and for the Loc-Pop-

Table 5. Comparison among set 1 (Pop-59) and set 2 (Loc-Pop) for studied traits at separate and across locations.

Sets	Beheira	Menofia	Bani Sweif	Minia	Combined
		KPP			
Set 1	608.3	566.1	460.0	627.6	565.5
Set 2	687.3	649.4	648.4	713.3	674.6
Diff	-79.0	-83.3	-188.4	-85.7	-109.1
		100KW (g)			
Set 1	29.6	26.3	29.7	26.3	28.0
Set 2	29.7	26.4	30.7	26.0	28.2
Diff	-0.1	-0.1	-1.0	0.3	-0.2
		OC (%)			
Set 1	9.1	8.9	8.4	8.6	8.7
Set 2	7.7	7.3	7.2	7.6	7.4
Diff	1.5	1.6	1.2	1.2	1.3
		PC (%)			
Set 1	9.6	10.1	11.0	10.1	10.2
Set 2	8.9	9.3	10.2	9.5	9.5
Diff	0.7	0.9	0.7	0.7	0.8
		CC (%)			
Set 1	68.4	68.3	68.2	68.3	68.3
Set 2	69.8	69.7	69.6	69.7	69.7
Diff	-1.3	-1.3	-1.3	-1.3	-1.4
		GYPP (g)			
Set 1	152.9	147.5	135.8	124.0	140.0
Set 2	212.5	165.6	202.2	138.1	179.6
Diff	-59.5	-18.1	-66.4	-14.2	-39.6
		OYPP (g)			
Set 1	13.8	12.8	10.9	10.6	12.1
Set 2	16.0	11.9	14.1	10.4	13.1
Diff	-2.2	0.9	-3.2	0.3	-1.1
		PYPP (g)			
Set 1	14.6	14.6	14.7	12.5	14.1
Set 2	18.7	15.3	20.0	13.1	16.8
Diff	-4.1	-0.7	-5.3	-0.6	-2.7

Diff = Difference = Set 1 - Set 2

HOC over its original population (Loc-Pop) by 1.9% (a relative improvement of 27.9%). It is interesting to mention that the magnitude of improvement for oil content was higher in Loc-Pop-HOC than that in Pop-59-HOC, indicating that the original population Loc-Pop was more responsive to selection for high oil content than Pop-59. This might be attributed to the fact that Pop-59 had a long history of improvement for high oil content; its average oil content across locations was 8.9%, while the Loc-Pop was subjected to only one cycle of S_1 recurrent selection for high oil content resulting in average oil content across locations of 6.8% (Table 6). Genetic variance amenable to selection for oil content might be more reduced in Pop-59 due to practicing several cycles of selection for this trait compared to Loc-Pop.

Table 6. Change in selected traits due to one cycle of S_1 recurrent selection in absolute (AC) and relative (RC %) values in developec populations compared to the original ones.

Trait	Location	Pop-59 -HOC		Pop-59 -HGY		Pop-59 -HOY		Loc-Pop -HOC		Loc-Pop -HGY		Loc-Pop -HOY	
		AC	RC%	AC	RC%	AC	RC%	AC	RC%	AC	RC%	AC	RC%
OC%	Beheira	1.4*	15.9	-1.8*	-19.9	0.6*	6.6	1.5*	21.2	-0.8	-11.5	1.0*	13.8
	Menofia	1.3*	13.6	-2.1*	-22	-1.1*	-11.3	1.9*	28.6	-0.9*	-13.4	2.2*	33.8
	Bani Sweif	1.2*	14.3	-2.4*	-27.3	-0.1	-1.2	1.7*	24.3	-1.0*	-14.3	0.1	1.9
	Minia	0.9*	10.9	-1.0*	-12.1	0.4*	4.3	2.5*	38.7	0.7*	10.8	1.3*	19.7
	Combined	1.2	13.7	-1.8	-20.4	0.0	-0.5	1.9*	27.9	-0.5	-7.4	1.2*	16.9
GYPP(g)	Beheira	-22.6*	-15.6	27.4*	18.9	26.3*	18.1	-37.2*	-19.8	81.0*	43.0	53.1*	28.2
	Menofia	-40.8*	-27.2	20.8*	13.9	10.0	6.7	-25.0*	-15.7	37.5*	23.6	13.3	8.4
	Bani Sweif	-15.6*	-13.6	72.7*	63.5	27.6*	24.1	-55.3*	-28.3	87.7*	44.8	-6.0	-3.0
	Minia	-55.3*	-28.3	87.7*	44.8	-6.0	-3.0	-20.0	-14.2	17.5	12.4	-8.3	-5.9
	Combined	-21.2*	-16.2	37.3*	28.6	21.8*	16.7	-34.4*	-20.1	55.9*	32.7	13.1	7.6
OYPP(g)	Beheira	-0.3	-2.0	-0.6	-4.8	3.4*	25.8	-0.5	-3.4	3.6*	26.6	6.1*	44.9
	Menofia	-2.4*	-16.9	-1.6	-11.2	-0.7	-5.3	0.9	9.0	0.7	7.1	4.7*	45.2
	Bani Sweif	-0.1*	-1.3	1.9*	18.8	2.3*	22.9	-1.4	-10.2	3.3*	24.2	0.0	-0.2
	Minia	0.5	5.2	1.0	10.4	2.5*	25.6	1.7	19.0	2.2*	24.5	1.1	12.1
	Combined	-0.6	-4.9	0.2	1.4	1.9*	15.8	0.2	1.7	2.5*	21.2	3.0*	25.4

*** indicates significance at 0.05 level of probability.**

2. Grain yield/plant

Results combined across locations (Table 6) indicated that selection for high grain yield/plant (GYPP) resulted in a significant improvement in GYPP by 28.6% for Pop-59-HGY over its original Pop-59 and 32.7% for Loc-Pop overits original Loc-Pop. The magnitude of the absolute improvement for GYPP is higher for Loc-Pop-HGY (55.9g) than that for Pop-59-HGY (37.3g). The higher response to selection for GYPP in the local population than in the exotic one (Pop-59) could be interpreted by the fact that Loc-Pop was not subjected previously to selection (this population is synthesized from selected farmer seeds in Egypt) and hence more adapted to local conditions compared to Pop-59, that was subjected to several cycles of improvement for high oil content and high grain yield.

3. Oil yield/plant

Results combined across the four locations (Table 6) indicated that one cycle of S_1 recurrent selection for high oil yield/plant resulted in a significant improvement in oil yield/plant of the Pop-59-HOY over its original population (Pop-59) by 1.9g (15 8%) and in Loc-Pop-HOY over Loc-Pop by 3.0g (25.4%). Since oil yield per plant is the product of its two components, *i.e.* oil content and grain yield/plant, the Loc-Pop showed higher responsiveness to improvement in oil yield/plant than Pop-59, because Loc-Pop showed higher responsiveness to selection for both oil content and grain yield/plant compared to Pop-59.

Changes in unselected traits

Selection for oil content was associated with a significant decrease in GYPP (-16.2 and-20.1%), kernels/plant (-12.3 and -22.4%) and carbohydrate content (an absolute value of -1.4 and -2.1% and a relative change of -2.0 and -3.0%). However, selection resulted in a significant increase in protein content (an absolute value of 1.1 respectively (Tables 5 and 7).

Improvement in grain yield/plant *via* one cycle of S_1 recurrent selection was accompanied with a significant increase in number of kernels/plant (23.7and12.8%), protein yield/plant (14.1 and 27.0%), and carbohydrates content (absolute values of 2.1 and 0.6% and relative values of 3.0 and 0.8%) for Pop-59-HGY and Loc-Pop-HGY, respectively, a significant increase in OYPP (21.2%), and 100kW (23.5%) for Loc-Pop-HGY only, and a significant decrease in oil content (an absolute value of 1.8% or relative value of 20.4%) and protein content (an absolute value of 1.2% or relative value of 11.6%) for Pop-59-HGY only (Tables 6 and 7).

Selection improvement in oil yield/plant was associated with a significant increase in grain yield per plant of 16.7% and in carbohydrate

Table 7. Values of absolute (AC) and relative changes (RC%) in unselected traits due to one cycle of S_1 recurrent selection in developed populations compared to the original ones.

Trait	Location	Pop-59 -HOC		Pop-59 -HGY		Pop-59 -HOC		Loc-Pop -HGY		Loc-Pop -HOC		Loc-Pop -HGY	
		AC	RC	AC	RC	AC	RC	AC	RC	AC	RC	AC	RC
KPP	Beheira	-105.4*	-17.4	52.2	8.6	60.9	10.0	-297.3*	-36.8	-22.3	-2.8	-165.3*	-20.4
	Menofia	-167.0*	-29.7	96.7	17.2	83.4	14.8	-167.2*	-23.5	63.5	8.9	-146.7*	-20.6
	Bani Sweif	-30.8	-7.7	178.6*	44.8	95.8*	24.0	-118.0*	-17.9	127.8*	19.4	-55.7	-8.4
	Minia	43.4	8.1	170.2	31.8	154.9	28.9	-60.7	-8.7	200.2	28.8	-64	-9.2
	Combined	-64.9	-12.3	124.5*	23.7	98.8	18.8	-160.8*	-22.4	92.3	12.8	-107.9	-15.0
100KW(g)	Beheira	8.2*	34.2	10.9*	45.4	3.5	14.4	1.6	6.4	9.3*	37.4	8.2*	33.0
	Menofia	1.3	4.9	-0.7	-2.6	-1.8	-6.6	2.5	10.9	4.7	20.9	8.0*	35.4
	Bani Sweif	-1.8	-6.3	5.1*	17.9	0.6	2.0	-3.8*	-12.7	6.3*	21.4	1.7	5.7
	Minia	0.5	1.9	0.6	2.3	-0.6	-2.4	-1.5	-6.0	3.6	14.4	1.7	6.8
	Combined	1.8	6.8	4.0	15.1	0.4	1.6	-0.3	-1.2	6.0*	23.5	4.9*	19.2
PC%	Beheira	0.6*	6.0	-1.3*	-12.7	-0.8*	-8.0	1.4*	16.4	-0.1	-1.5	0.2	2.3
	Menofia	1.8*	17.4	-2.0*	-18.6	-1.5*	-14.5	1.6*	18.2	0.4	4.3	0.7	8.1
	Bani Sweif	0.7*	6.0	-1.2*	-10.7	-0.4	-3.3	1.0*	9.9	-0.3	-3.3	-0.1	-0.6
	Minia	1.4*	13.7	-0.4	-4.0	0.0	0.3	1.0*	10.3	-0.7	-7.1	0.0	-0.3
	Combined	1.1*	10.7	-1.2*	-11.6	-0.7*	-6.4	1.2*	13.5	-0.2	-2.1	0.2	2.2
CC%	Beheira	-1.2*	-1.8	2.7*	3.9	0.4*	0.6	-2.3*	-3.3	0.7*	1.0	-0.6*	-0.8
	Menofia	-1.6*	-2.4	2.2*	3.3	1.8*	2.6	-1.9*	-2.6	0.4*	0.5	-0.8*	-1.1
	Bani Sweif	-1.0*	-1.5	2.0*	2.9	0.7*	1.0	-2.0*	-2.9	0.7*	1.0	0.4	0.5
	Minia	-1.6*	-2.3	1.4*	2.0	-0.4	-0.5	-2.1*	-3.0	0.6*	0.8	-0.3	-0.5
	Combined	-1.4*	-2.0	2.1*	3.0	0.6*	0.9	-2.1*	-3.0	0.6*	0.8	-0.3	-0.5
PYPP(g)	Beheira	-1.5*	-10.6	0.6	4.1	1.3*	9.0	-1.1	-6.8	6.5*	40.6	5.0*	31.2
	Menofia	-2.3*	-14.5	-1.1	-7.1	-1.4	-8.8	0.0	-0.2	3.9*	28.6	2.3	17.0
	Bani Sweif	-1.1	-8.3	6.0*	46.5	2.6*	20.3	-4.1*	-21.0	5.9*	30.1	-0.7	-3.6
	Minia	0.9	7.8	2.2*	19.8	2.3*	20.9	-0.7*	-5.3	0.6*	4.5	-0.8*	-6.0
	Combined	-1.0	-7.4	1.9*	14.1	1.2	8.9	-1.5	-9.5	4.3*	27.0	1.5	9.3

content (an absolute value of 0.6 and relative value of 0.9%), for Pop-59-HOY and increase in oil content (an absolute value of 1.2% and a relative value of 16.9%) and 100KW (19.2%) for Loc-Pop-HOY and a significant decrease in protein content (an absolute value of -0.7 or a relative value of -6.4%) for Pop-59-HOY.

Trait interrelationships

Genetic correlation coefficients (r_g) between chosen traits of each set of populations and across sets across locations are presented in Table (8). A strong (highly significant) positive genetic association was recorded between GYPP and PYPP (r_g = 0.94, 0.97 and 0.94 for set 1, set 2, and across sets, respectively).Thus selection for high grain yield/plant would simultaneously increase grain yield and protein yield/plant. Moreover, the genetic correlation between GYPP and OYPP was highly significant and positive (r_g = 0.78) across all studied populations, indicating also that selection for high grain yield/plant will simultaneously increase oil yield. Grain yield/plant was correlated positively with CC% (0.68**), KPP (0.58**) and 100KW (0.52**) across populations, indicating that selection for high GYPP would improve the grain carbohydrate content and that the improvement of GYPP would come from the improvement of the yield components, number of kernels/plant and kernel weight. Oil yield/plant showed a significant and positive genetic correlation with protein yield/plant (0.77**), suggesting that selection for high oil yield would also improve protein yield. It is worthy to note that a strong negative genetic correlation was also obtained between protein content and carbohydrate content (r_g = -0.91**,-0.84** and -0.83** for set 1, set 2 and across sets, respectively).

The genetic correlation between grain yield/plant and oil content was negative and significant (r_g = -0.61, -0.76 and -0.63 for Set 1, Set 2 and across sets, respectively). Negative correlations between oil content and yield in maize are frequently reported, suggesting that simultaneous selection for both traits is difficult (Misevic and Alexander 1989, Tatis 1990 and Dudley and Lambert 1992).

Associations between protein and oil content varied in the literature from insignificant (Dorsey-Redding *et al* 1991 and Sene *et al* 2001) to highly positive (Song *et al* 1999). However, associations found in this work were of favorable direction, indicating potential for simultaneous selection of protein and oil contents. This conclusion agrees with other reports (Pollmer *et al* 1978a and b, Mittelmann *et al* 2003, Dudley *et al* 2007 and Medici *et al* 2009).

A strong positive correlation was found between OC% and PC% (0.76**, 0.67** and 0.63**), and a very strong negative correlation was recorded between OC% and CC% (-0.90**, -0.91**, and -0.89**) for set 1, set 2 and across sets, respectively. This indicated that selection for high

Table 8. Genetic correlation coefficients (r_g) between pairs of chosen traits of each set of populations and across the two sets.

Trait pairs	Pop-59 (n=48)	Loc-Pop (n=48)	Combined (n=96)
OC % *vs* GYPP	-0.61**	-0.76**	-0.63**
OC % *vs* OYPP	ns	-0.41**	ns
OC % *vs* PC	0.76**	0.67**	0.63**
OC % *vs* CC	-0.90**	-0.91**	-0.89**
OC % *vs* PYPP	-0.41**	-0.65**	-0.50**
OC % *vs* 100KW	ns	-0.58**	-0.24*
OC % *vs* KPP	-0.67**	-0.52**	-0.58**
GYPP % *vs* OYPP	0.68**	0.89**	0.78**
GYPP % *vs* PC	ns	-0.38**	-0.57**
GYPP % *vs* CC	0.74**	0.66**	0.68**
GYPP % *vs* PYPP	0.94**	0.97**	0.94**
GYPP % *vs* 100KW	0.36**	0.74**	0.52**
GYPP % *vs* KPP	0.71**	0.49**	0.58**
OYPP % *vs* PC	-0.27*	ns	-0.33**
OYPP % *vs* CC	ns	0.36**	0.23*
OYPP % *vs* PYPP	0.76**	0.91**	0.77**
OYPP % *vs* 100KW	0.38**	0.61**	0.43**
OYPP % *vs* KPP	0.30**	0.39**	0.33**
PC % *vs* CC	-0.91**	-0.84**	-0.83**
PC % *vs* PYPP	-0.43**	ns	-0.27*
PC % *vs* 100KW	ns	ns	ns
PC % *vs* KPP	-0.74**	-0.76**	-0.71**
CC % *vs* PYPP	0.51**	0.49**	0.48**
CC % *vs* 100KW	ns	0.45**	0.28*
CC % *vs* KPP	0.75**	0.63**	0.68**
PYPP % *vs* 100KW	0.38**	0.77**	0.57**
PYPP % *vs* KPP	0.57**	0.33**	0.41**
100KW % *vs* KPP	ns	ns	ns

* and** indicated significance at 0.05 and 0.01 levels of probability, respectively.

OC% was accompanied by an increase in protein content, but with a decrease in carbohydrate content. It is worthy to
mention that OC% showed a significant negative correlation with GYPP (r_g = - 0.63** and - 0.50** for combined data), indicating that selection for higher oil content would decrease grain yield and protein yield/plant.

Comparing actual with predicted progress

In general, estimates of actual progress in this study for oil content, grain yield and oil yield/plant as a result of one cycle of S_1 recurrent selection were much lower than predicted progress (Table 9). This could be ascribed to the overestimation of the heritability based on the total genetic variance (in broad sense). It is believed that a considerable amount of non-heritable (dominance and epistasis) components is included in genetic variance estimates.

Table 9. Actual *vs* predicted gain from one cycle of S_1 recurrent selection for oil content (OC), grain yield (GYPP) and oil yield (OYPP) per plant in Pop-59 and Loc-Pop maize populations.

Trait	Pop-59		Loc-Pop	
	Predicted* gain %	Actual gain %	Predicted* gain %	Actual gain %
OC%	37.35	13.70	71.41	27.90
GYPP	61.30	28.60	43.84	32.70
OYPP	73.50	15.80	66.15	25.40

* Al-Naggar *et al* (2011).

Both predicted and actual progresses (Table 9) in oil content (OC%) indicated that Loc-Pop is about two-fold more responsive to OC% selection than Pop-59. Moreover, predicted and actual progresses indicated higher response to selection for GYPP improvement in Loc-Pop than Pop-59.

On the contrary, predicted improvement in oil yield/plant (66.15%) was higher for Pop-59; their actual improvement (15.8%) compared to 25.4% for Loc-Pop which may be partially attributed to the lower response to selection for GYPP in Pop-59 (28.6%) than in Loc-Pop (32.7%) (Al-Naggar *et al* 2011).

Actual progress in oil content achieved *via* one cycle of selection by other investigators ranged from 0.14% (Dudley and Lambert 1992) to 1.01% (Wang *et al* 2009) and 1.18% (Song and Chen 2004).The higher actual gains from selection per cycle achieved in the present study in the newly developed populations (from 1.2 to 1.9) as compared to previous reports may be attributed to the presence of more variation in the original populations (especially the Loc-Pop) that is amenable to selection and to the application of the S_1 progeny selection method, which utilizes the additive genetic variance in a better way than other methods and presents an opportunity for selection against major deleterious recessive genes that become homozygous with inbreeding (Genter 1971 and 1973, Tanner and Smith 1987 and Hallauar and Miranda 1988). Our results are more or less comparable to those obtained by Gamea (2005) *via* one cycle of S_1 recurrent selection for higher oil content and higher oil yield/plant. The new HOM populations developed in this study are available to maize breeding programs as suitable germplasm to extracting inbred lines for developing HOM single and 3-way cross hybrids that could contribute in narrowing the gaps of edible oils and cereal crops in Egypt.

REFERENCES

A. O. A. C. (2000). Official Methods of Association of Analytical Chemists, 13th ed. Washington D.C., USA.

Alexander, D. E., A. S. Silvel, L., F. I. Collins, and R. C. Rodgers (1967). Analysis of oil content of maize by wide-line NMR. J. Am. Oil Chem. Soc. 44:555-558.

Al-Naggar, A.M.M., M.M.M. Atta and H.T.O. Hassan (2011). Variability and predicted genetic gain from selection for grain oil content and yield in two maize populations. . Egypt J. Plant Breed. 1: 1-12.

Al-Naggar, A. M. M., M. A., El-Lakany, H. Y. El-Sherbieny, and W. M. El-Sayed (2010). Inheritance of grain oil content and yield characteristics in maize. Egypt J. Plant Breed., 14(2):239-264.

Berke, T. G. and T. R. Rocheford, (1995). Quantitative trait loci for flowering, plant and ear height, and kernel traits in maize. Crop Sci. 35:1542-1549.

Dorsey-Redding, C., C. H., Hurburgh L. A. Johnson, and S. R. Fox (1991). Relationships among maize quality factors. Cereal Chemistry 68:602-605.

Dudley, J. W. and R. J.Lambert, (1992). Ninety generations of selection for oil and protein in maize. Maydica 37:81-87.

Dudley, J. W. and R. J. Lambert, (2004). Hundred generations of selection for oil and protein in corn. Plant Breed. 24:79-110.

Dudley, J. W., D., Clark, T. R. Rocheford, and J. R. Le Deaux (2007). Genetic analysis of corn kernel chemical composition in the random mated 7 generation of the cross of generations 70 of IHP × ILP. Crop Sci. 47:45-57.

El-Agamy, A. I., S. B. Mourad, and S. E. Sadek (1992). Selection based on S_1 evaluation traits is being used by many maize breeders as it helps for developing inbred lines and improving maize populations. Egypt J. Appl. Sci. 7: 76-89.

East, E. M. and D. F. Jones (1920). Genetic studies on the protein content of maize. Genetics 5:543-610.

Gamea, H. A. A. (2005). Estimation of genetic variance components of yield and oil percentage in some new maize genotypes. M. Sc. Thesis, Fac. of Agric., Menofia Univ., Egypt.

Genter, C. F. (1971). Yield of S_1 lines from original and advanced synthetic varieties of maize. Crop Sci. 11: 821-824.

Genter, C. F. (1973). Comparison of S_1 and test-cross evaluation after two cycles of recurrent selection in maize. Crop Sci. 13: 524 - 527.

Genter, C. F., J. F.Eheart, and W.N.Linkous (1956). Effects of location, hybrid, fertilizer and rate of planting on the oil and protein contents of corn grain. Agron. J. 48:63-67.

Getschman, R. J. and A. R. Hallauer (1991). Genetic variation among and within S_1 progenies of maize. J. of the Iowa Academy of Sci. 3:127-135.

Goldman, I., T. R. Rocheford, and J. W Dudley (1994). Molecular markers associated with maize kernel oil concentration in an Illinois high protein × Illinois low protein cross. Crop Sci. 34:908-915.

Hallauer, A. R. and J. B. Miranda (1988). Quantitative genetics in maize breeding. 2nd edition. Iowa State Univ. Press, Ames, Ia, U.S.A, 469 p.

Han, Y., C. M. Parsons and D. E. Alexander (1987). The nutritive value of high-oil corn for poultry. Poult. Sci. 66:103-111.

Lambert, R. J., D. E. Alexander and I. J.Mejaya (2004). Single kernel selection for increased grain oil in maize synthetics and high oil hybrid development. Plant Breed. Rev. 24:153-176.

Lambert R. J., D. E. Alexander, and Z. L. Han (1998). High oil pollinator enhancement of kernel oil and effects on grain yields of maize hybrids. Agron. J. 90: 211-215.

Letchworth, M. B. and R. L. Lambert (1998). Pollen parent effects on oil, protein and starch concentration in maize kernels. Crop Sci. 38: 363-367.

Mahmoud, A. A., F. H. S. Soliman and A. M. Shehata (1999). Evaluation of S_1 progenies of maize composite Giza-2 (C-8). Egypt J. Plant Breed. 3: 115-125.

Mazur, B., E. Krebbers and S. Tingey (1999). Gene discovery and product development for grain quality traits. Science, 285:372-375.

Medici, L. O., S. A. Gaziola, V. A. Varisis, J. A. C. Paula, R. R. Ferriera and R. A. Azevedo (2009). Diallelic analysis for lysine and oil contents in maize grains. Sci. Agric. 66(2): 204-209.

Miller, R. I., J. W. Dudley and D. E. Alexander (1981). High intensity selection for percent oil in corn. Crop Sci. 21 433-437.

Misevic, D. and D. E. Alexander (1989). Twenty-four cycles of phenotypic recurrent selection for percent oil in maize. I. *per se* and testcross performance. Crop Sci. 29 : 320-324.

Mittelmann, A., J. B. Miranda, G. J. M. Lima, C. Haraklein and R. T. Tanaka (2003). Potential of the ESA23B maize population for protein and oil content improvement. Sci. Agric. 60(2):319-327.

Moose, S. P., J. W. Dudley, and T. R. Rocheford (2004). Maize selection passes the century mark: A unique resource for 21st century genomics. Trends Plant Sci. 9:358-364.

Munamava, M. R., A. S. Goggi and L. Pollak (2004). Seed quality of corn inbred lines with different composition and genetic backgrounds. Crop Sci. 44:542-548.

Pixley, K. V. and M. S. Bjarnason (2002). Stability of grain yield, endosperm modification and protein quality of hybrid and open-pollinated quality protein maize (QPM) cultivars. Crop Sci. 42:1882-1890.

Pollmer, W. G., D. Eberhart, and D. Klein (1978a). Inheritance of protein and yield of grain and stover in maize. Crop Sci. 18:757-759.

Pollmer, W. G., D. Eberhart, D. Klein and B. S. Dhillon (1978b). Studies on maize hybrids involving inbred lines with varying protein content in maize. Crop Sci. 80:142-148.

Séne, M., C. Thévenot, D. Hoffmann, F. Bénétrix, M. Causse and J. L. Prioul (2001). QTLs for grain dry milling properties, composition and vitreousness in maize recombinant inbred lines. Theor. Appl. Genet. 102:591-599.

Snedecor, G. W. and W. G. Cochran (1989). Statistical Methods. 8[th] ed. Iowa State Univ. Press, Ames, USA.

Soliman, F. H. S., SH. A. Shafay, A. I. El-Agamy and M. A. I. Mostafa (2007). Inheritance of grain yield and oil content in new maize high oil single-crosses. Egypt. J. Plant Breed. 11:507-530.

Song, T. M. (2001). High-oil corn breeding and development prospect in China. Rev. China Agric. Sci. Tech. 3:40-43.

Song, T. M., F. Kong, C. J. Li and G. H. Song (1999). Eleven cycles of single kernel phenotypic recurrent selection for percent oil in Zhongzong No. 2 maize syn. J. of Genetics and Breed. 53: 31-35.

Song, T. M. and S. J. Chen (2004). Long-term selection for oil concentration in five maize populations. Maydica 49: 9-14.

Tanner, A. H. and D. S. Smith (1987). Comparison of half-sib and S_1 recurrent selection in the Krug Yellow Dent maize populations. Crop Sci. 27: 509-513.

Tatis, H. A. (1990). Seleção para alto teor de óleo na semente de milho e seus efeitos sobre caracteres agronomic. Piracicaba: USP/ESALQ, (Tese - Doutorado), 118 p. Cited by Mittelmann *et a.* (2003).

Wang, X. L. and B. A. Larkins (2001). Genetic analysis of amino acid accumulation in *opaque-2* maize endosperm. Plant Physiol. 125:1766-1777.

استنباط عشائر جديدة من الذرة الشامية عالية الزيت باستخدام دورة واحدة من الانتخاب الدورى لسلالات جيل الاخصاب الذاتى الاول

أحمد مدحت محمد النجار[١]، محمد محمد محمد عطا[١]، هشام توفيق عثمان حسن[٢]

١- قسم المحاصيل- كلية الزراعة- جامعة القاهرة- جيزة.
٢- قسم بحوث الذرة الشامية، فاين سيدز إنترناشيونال، مصر

إن استنباط عشائر ذرة عالية الزيت هو متطلب أساسى لعزل سلالات تربية داخلية مناسبة لاستنباط هجن ذرة عالية الزيت. فى الدراسة الحالية تم استنباط ستة عشائر جديدة عالية الزيت؛ ثلاثة من العشيرة المستوردة من تايلاند (Pop-59) وثلاثة من العشيرة المحلية (Loc-Pop) عن طريق دورة واحدة من الانتخاب الدورى

لسلالات جيل الاخصاب الذاتى الاول لمحتوى زيت عالى ومحصول حبوب عالى ومحصول زيت عالى. تم تقييم العشائر الست الناتجة بجانب عشيرتى الاساس فى ربعة مواقع هى كوم حمادة (محافظة البحيرة)، أشمون (محافظة المنوفية)، ببا (محافظة بنى سويف)، بنى عبيد (محافظة المنيا). كان التحسين الحقيقى المتحصل عليه فى محتوى زيت الحبة ومحصول حبوب النبات ومحصول زيت النبات هو 1,2%، 37,39 جم، 1,9جم بالنسبة للعشائر Pop-59-HOC و Pop-59-HGY و Pop-59-HOY و 1,9%، 55,9 جم، 3,0جم للعشائر Loc-Pop-HOC و Loc-Pop-HGY و Loc-Pop-HOY، على التوالى. كانت تقديرات التحسين الحقيقى أقل بكثير من التقديرات المتوقعة للتحسين، وأعزى ذلك الى ان قيم كفاءة التوريث المستخدمة كانت مبالغا فيها، لاعتمادها على التباين الوراثى الكلى (لاستخدام قيم كفاءة التوريث بالمعنى الواسع). كان الانتخاب لصفة محصول الزيت/النبات مصحوبا بزيادة معنوية فى محصول الحبوب/النبات وفى محتوى الكربوهيدرات ومحتوى الزيت بالحبة بينما أدى لنقص معنوى فى نسبة بروتين الحبة. وأدى التحسين بالانتخاب لصفة محتوى الزيت بالحبة الى انخفاض معنوى ملحوظ فى محصول حبوب النبات وفى محتوى الكربوهيدرات وعدد حبوب النبات، بينما أدى الى زيادة معنوية فى محتوى البروتين بالحبة.