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RESPONSE TO EARLY GENERATION SELECTION FOR YIELD AND ITS COMPONENTS IN BARLEY CROSSES.

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ABSTRACT: *Considerable improvements of barley genotypes with higher yield have been achieved with different breeding methods. The objectives of this research were to compare the response to direct early generation selection for grain yield per se and indirect selection via its components using Fasoulas, 1973 honeycomb design to select F_2 plants in three barley crosses. Two systems for response to selection were evaluated; Individual selection in F_2 plants with response in F_3 and line selection in F_3 with response in F_4. A selection intensity of 5% was imposed for each of high and low expressions of each trait among F_2 plants and F_3 lines.*

Realized heritability estimates (RH) for number of kernels/spike were relatively the highest estimated from selection in F_3-F_4 in the first and the second cross with values 73.3 and 83.5, respectively and intermediate in the third cross (67.4) and 1000-kernel weight were intermediate in ranging (61.1-66.1) and to lesser extent for grain yield, while the lowest values were recorded for no.of spikes/plant and grain yield in all crosses. Realized heritabilities (RH) estimated from selection in F_3 –F_4 were relatively higher than those from selection in F_2-F_3 for yield and its components for all crosses.

The highest proportion of the high yielding lines in F_4 resulted from selection for kernel weight and number of kernels per spike and the lowest effectiveness was detected for number of spikes per plant. To reduce environmental variation among F_2 plants, selecting for heavy and more kernels appears to be effective in improving barley grain yield by using modified early-generation selection; i.e. Fasoulas design.

Key Words: *Efficiency of selection, Honeycomb selection, individual plant selection, realized heritability.*

INTRODUCTION

Barley (*Hordeum vulgare* L.) is a crop with great adaptative potential in many regions of the world. In areas which have only short rainy season, growers can obtain a harvest mainly because this crop has advantages in aspects such as salt tolerance, frost tolerance in the early period of development, drought tolerance etc. (Esparza and Foster, 1998).

Although yield is the primary objective in many programs, selection for yield follows selection for traits of higher heritability such as disease resistance (O'Brien *et al.*, 1978). Makenzie and Lambert (1961), Shebeski (1967) and Wagoire *et al.* (1999 b) have suggested that selection for yield should commence in the earliest possible generation.. In the past, barley breeders have increased grain yield by selecting for yield *per se*. Breeding for yield components produced mixed results (Abdelkader *et al.*, 1984, Sharma, 1994). Breeding for ideal plant traits to maximize grain yield is difficult because of both genotype x environment interactions and the presence of allometric relationships in cearels (Grafius *et al.*, 1976).

Parental selection is important because it determines the range and nature of the variability in the F_2 generation and sets the potential limit for success in the segregating generations. Mahdy (1988) found that selection based on grain yield *per se* was effective in improving grain yield itself and was accompanied by a sizeable significant increase in number of spikes /plant and grain numbers / spike.

Plant breeders work with quantitative characters, which are controlled by many genes whose Individual effects are too small to be detected by conventional Mendelian analysis . Hence, the properties and actions of these genes have to be inferred from analysis of the means and variances of appropriate generations or populations (Mather and Jinks 1982, Falconer and Mackay 1996, Kearsey and Pooni 1996, Hill *et al.*, 1998 and Wagoire *et al.*, 1999 b).

Knowledge of heritability is very important to the breeder since it quantifies the expected improvement upon selection. For practical breeding, it is desirable to estimate realized heritability which directly indicate the parent offspring relationships.

Realized heritability in cereal crops have been the subject of numerous investigations, of these Tripathi *et al.*, 1983, Theoulakis *et al.*, 1992 and Yoshiro and Takeda, 1997 in barley, Saadalla, 1994, Sharma, 1994, Hamada *et al.*, 1997, Wagoire *et al.*, 1999 a and b in wheat.

Fasoulas (1973) proposed the honeycomb design for selecting single F_2 plants to improve the heritability of plant yield. Mitchell *et al.*, 1982 reported that Fasoulas method was marginally superior to mass selection based on unadjusted single plant yields. However, the effectiveness of this method is not clearly reported for yield components. Grain yield improvement by a yield component selection should be superior to selection for yield *per se* when the component trait has a higher heritability than yield and the genetic correlation between this trait and yield is high (Falconar and Mackay, 1996).

Therefore, this investigation was undertaken to obtain information on the realized heritability for yield and yield components from F_2 – F_3 and F_3 - F_4 generations of three crosses. These genetic parameters may be helpful to the breeder to increase the efficiency of direct selection to yield by determining the most promising characters which could be effectively used as selection index for improving barley grain yield.

The objectives of this study are:

1- To determine the relative efficiency of both direct and indirect selection for improving grain yield.
2- To identify the most superior lines in three barley crosses by using modified early generations selection.

MATERIALS AND METHODS

The present investigation was carried out during the three successive growing seasons, i.e. 2000/01 at Shoubrababel, El-Mehalla El-Kubra, El-Gharbia Governorate, and the second season 2001/02 was at the Exp. Farm, Fac. of Agric. Tanta, Tanta Univ., and the final season 2002/03 was at El-Eslahe, Nawag, El-Gharbia Governorate, Egypt. The F_1 seeds were grown in the Exp. Farm Fac. of Agric. Tanta University. The genetic materials used in the present study included five genetically diverse varieties or lines *viz*, Line1, Giza124, Giza125, Giza126, and Plaisant (Table 1).

These parents were chosen on basis of previous information regarding their agronomic performance, representing a fairly wide range of variation for yield and its components. The following three crosses were made between the chosen parent,

(1)- Giza125 x Plaisant (2)-Line 1 x Plaisant (3)- Giza124 x Giza126

Table (1) Genotype, cross and pedigree and source of the parental cultivars

Genotype	Cross and pedigree	Source
Line 1	Campillo Lierena/Daphne // Sen " S"CMB 87A-658-M-3 M-3 Y-IB-OY.	ICARDA
Giza 124	Giza 117/ Bahteem 52 // Giza 118/ FAO 86. Line 366.16.2	Local
Giza 125	Giza117/ Bahteem 52//Giza118/FAO 86	Local
Giza 126	Balady Bahteem / SD729- por 12762-BC	Local
Plaisant	Introduced variety from France	France

The F_2 generation of these crosses were grown in the 2000/01 season. 500 F_2 plants for each cross were planted 30 cm. apart in a honeycomb design as described by Fasoulas (1973) using the local varieties Giza 125 and Giza 126 as a check. Divergent selection was applied among F_2 plants. If the yield and/or some of its component was higher or lower than all its adjacent neighbors, a plant was selected. Furthermore, the number of the selected plants was reduced to achive a selection intensity of 5% where the most extreme 25 plants were selected in each side of trait expression.

In 2001/02 season, seeds from the selected F_2 plants were planted in a single row, 1 m long, 25 cm. apart and seeded with 100 seeds in a randomized complete block design with two repliactions.

A divergent selection of intensity 5% was applied to select the most extremes among 200 F_3 lines in each cross for each of yield and its components. A total of 80 F_3 lines was selected where 10 lines were selected in each side of a trait expression. In 2002/03, the selected lines were seeded as F_3 derived F_4 lines and were evaluated in a randomized complete block design with four replications. Plot size and seeding rate were the same as the previous season.

The following traits were recorded in each generation as follows:

1-Number of spikes /plant. It was determined by counting the fertile tillers for F_2 plants and in 0.5 m long of F_3 and F_4 plots.

2-Number of kernels per spike as average of the 5 tallest culms in F_2 plants, and from 10 random main stems in F_3 and F_4 plots.

3-1000-kernel weight (g).

4-Grain yield per plant (g), determined as yield of spaced F_2 plants and of 1 m. long of each plot in F_3 and F_4

Two systems of selection were developed. Individual plant selection among F2 plants with response in F3 and selection among F3 lines with response in F4. Realized heritability (RH) was calculated according to Alexander et al., (1984) and Theoulakis et al., (1992) by the following formula:-

$$RH = (H_{t+1} - L_{t+1}) / (H_t - L_t)$$

whereas H and L refers to the mean values of the selected high and low groups for the same trait, and the subscripts (t) and (t+1) denote the generation in which selection was occurred and the subsequent generation in which the response was measured, respectively.

The relative efficiency for both direct selection for grain yield per se and indirect selection via its components were compared by tracing yields of different groups in consecutive generations in the two selection systems. Superior F4 yielding lines were used as another measure to determine the effectiveness of selection by tracing back the 10 highest yielding lines of each population to their F2 and F3 selected parents.

RESULTS AND DISCUSSION

Plant breeder must make choice as to when and how to practice selection. Selection is commonly delayed until latter generations. However, the breeder has the option of early selection and the selection criterion may be yield one or more of the yield components (Rasmusson and Cannell,1970). The effectiveness of early generation selection also depends on the amount of heritability and phenotypic variation.

In cross with relatively little genetic variation, early generation selection will be less effective or perhaps not effective.The differences between selection for both of high and low groups in the F_2 population were greater than those derived from F_3 and F_4 populations (Table 2). These wide ranges of variability may be partially due to the selection in F_2 population were carried out among spaced plants and consequently more variability were expressed in this concern. However, the persistence of large differences between selected high and low groups in F_3 and F_4 suggested the effectiveness of selection in these populations (Table 2).

Table (2): Means for the selected groups of F_2, F_3 and F_4 for high and low yield and yield components.

Crosses		Cross 1			Cross 2			Cross 3		
Trait	Gen.	High (H)	Low (L)	(H-L)	High (H)	Low (L)	(H-L)	High (H)	Low (L)	(H-L)
Number of spikes/plant	F_2	19.6	8.2	11.4	19.6	7.0	12.6	18.8	8.0	10.8
	F_3	20.3	14.7	5.60	17.0	12.6	4.40	18.5	13.8	4.70
	F_4	18.8	16.6	2.20	14.6	12.9	1.70	17.6	15.6	2.00
Number of kernels/spike	F_2	68.8	48.6	20.2	69.7	48.0	21.7	73.7	45.8	27.9
	F_3	71.3	61.2	10.1	70.8	59.3	11.5	75.8	62.3	13.5
	F_4	69.4	62.0	7.40	68.5	58.9	9.60	69.7	60.6	9.10
1000- kernel weight (g)	F_2	48.7	40.0	8.70	49.8	36.0	13.8	45.9	36.6	9.30
	F_3	44.6	41.0	3.60	46.1	40.2	5.90	43.7	39.4	4.30
	F_4	42.1	39.9	2.20	43.9	40.0	3.90	41.8	39.0	2.80
Grain yield /plant (g)	F_2	69.2	33.0	36.2	61.4	37.0	24.4	60.8	38.2	22.6
	F_3	70.6	56.2	14.4	71.4	61.2	10.2	68.7	61.9	6.80
	F_4	67.5	59.7	7.80	65.3	60.1	5.20	64.1	60.2	3.90

Estimates of heritability calculated from selection experiments are referred to as realized heritability (RH), because they measure directly the expected response to a given selection intensity. Furthermore, a comparison of RH with other methods of calculating heritability allows potential bias in this calculation to be detected. As indicated by Falconer and Mackay, 1996, RH may provide a biased heritability estimate for a population because of changes unrelated to selection in the refrence population, such as systemic shifts due to environmental effects, inbreeding depression , or random drift.

Realized heritabilities (Table 3) are useful measures for both of the effectiveness of selection and comparison of different selection methods (Falconer and Mackay, 1996). The realized heritability estimates derived from the selection in F_3 and response in F_4 should be more reliable than those estimated from selection in F_2 and response in F_3 owing to both of F_3 and F_4 values were based on means across replications, solid seeded plots and more stable inbred genotypes. In this study, the effectiveness of F_3 population selection for yield was determined by response of derived F_4 bulks. However, from the breeding view point, not only the response is important but also the absolute values of yield of lines derived by the breeding method. Moreover, Mitchell *et al.* (1982) found that the variability between the results may be attributed to the environmental conditions in the different seasons. (Table 3) shows the realized heritabilites (%) for yield and its components in the three barley crosses. The realized heritability estimates by selection in F_3 were high for number of kernels/spike and intermediate for 1000- kernel weight and moderate for grain yield in all crosses. Also, it is clear that the realized heritability estimated were generally high and differ from one cross to another and from one generation to other.

Table (3) : Realized heritability (%) for yield and its components in three barley crosses.

Trait	S-R system	Cross 1	Cross 2	Cross 3
Number of spikes/plant	F_2- F_3	49.1	34.9	43.5
	F_3- F_4	39.3	38.6	42.6
Number of Kernels /spike	F_2- F_3	50.0	53.0	48.4
	F_3- F_4	73.3	83.5	67.4
1000-Kernel weight	F_2- F_3	41.4	42.8	46.2
	F_3- F_4	61.1	66.1	65.1
Grain yield /plant	F_2- F_3	39.8	41.8	30.1
	F_3- F_4	54.2	51.0	57.4

Simane *et al.*(1993), Olmedo- Arcega *et al.*(1995) and Dencic *et al.*(2000) found that, when other yield components are held constant, increased kernels weight per spike resulted in increasing yield. Saadalla (1994) and Hamada *et al.*(1997) reported that kernels weight and kernels number /spike were good characters for indirect selection for yield improvement whereas spikes number / plant was not.

The components of grain yield in cereal crops are determined at different stages in the outgoing of plants. Number of spikes/plant is determined at an early stage. In wheat, number of spikelets is determined at time of floral initiation, but variation in number of florets per spike can occurred. In barley, spikelet production can extend for a longer period, but there is only one floret per spike (Bonnet, 1966). In both species, however, the upper limit of kernel number is determined before head emergence. Kernel size is partly determined during vegetative growth, but is largely a function of the post (Thorne, 1966). Since yield components are determined at different times, they are differentially affected by variation in environment. For example, in wheat, low temperature between spikelet initiation and anthesis period reduced tiller number, short days during the same period reduced kernel number per spike; and short days after anthesis period reduced kernel weight. In each case the other components were only slightly affected. (Thorne. *et al*, 1968).

Thus, realized heritability (RH) from selection in F_3 -F_4 were relatively the highest estimate for number of kernels / spike in the first and the second cross with values 73.3 and 83.5, respectively, and intermediate in the third cross 67.4 and for 1000-kernel weight was 61.1 in the first cross, 66.1 in the second cross and 65.1 in the third cross, and to lesser extent for grain yield in all crosses with values 54.2, 51.0 and 57.4, respectively, while the lowest values were recorded for number of spikes / plant in all crosses. Heritabilities estimated from selection in F_3-F_4 were relatively higher than those from selection in F_2-F_3 for yield and its components in all crosses except, for number of spikes/plant in cross 1 (Table 3). Low heritability estimates for grain yield than some yield components was previously reported by Joshi *et al.* (1968), Smith (1976) and Saadalla (1994). The intermediate magnitude of (RH) for grain yield and high magnitude for number of kernels / spike and 1000- kernel weight demonstrated the effectiveness of selection especially for 1000- kernel weight and number of kernels /spike, while it was less pronounced for number of spikes and grain yield (Table 3). Hamada (1988), found that the differences of realized heritability values from cross to another might be due to the differences in the genetic constitution of parental genotypes involved in these crosses, while the differences in this respect between generations could be due to the environmental fluctuation; since these generations were raised in different years indicating the influences of genotype x environment interaction component on the total phenotypic variance.

Table 4 shows the influence of direct selection for grain yield and indirect selection *via* yield components. In all crosses, selection for higher groups of yield and yield components produced progenies with higher grain yield than selection for lower groups. However, selection for high number of spikes /plant was not significant for increasing grain yield in both selection systems in the three crosses, while selection for number of kernels / spike gave significant increases for grain yield in both selection systems in the first cross, while it was significant in F_3-F_4 selection response system in the second cross. The most effective indirect selection for grain yield was reported for kernels weight which showed the highly significant increases in grain yield in both selection-response systems in all crosses. Also Table 4 shows that, the direct selection for grain yield was effective in increasing grain yield. However, the high response in grain yield was associated with the selection for kernels weight, which slightly exceeded the response for direct selection in F_3-F_4 selection-response system in all crosses. The effectiveness of indirect selection *via* kernel weight in increasing grain yield was reported by Sidwell *et al.* (1976) and Alexander *et al.*(1984) and Saadalla (1994). Since kernel weight can usually be measured more precisely and at less expense than grain yield, selection for kernels weight in early generations was advised by Alexander *et al.* (1984). This conclusion is supported in this study. However, selection for high tillering ability may be not effective in improving yield under normal seeding rate where plants did not get the chance to express its full potential for this trait.

Table (4): Grain yield response measured as progeny mean from direct selection for yield and indirect selection *via* yield components for three barley crosses in two selection-response (S-R) systems.

Traits	S-R System	Cross 1 Selection groups			Cross 2 Selection groups			Cross 3 Selection groups		
		High (H)	Low(L)	H-L	High (H)	Low(L)	H-L	High (H)	Low(L)	H-L
Number of spikes/ plant	F_2-F_3	173.5	155.3	18.2	170.4	161.3	9.1	158.3	139.6	18.7
	F_3-F_4	166.8	149.8	17.0	161.2	147.2	14.0	156.2	139.9	16.3
No.of kernels / spike	F_2-F_3	202.8	170.4	32.4**	187.8	174.4	13.4	186.4	172.5	13.9
	F_3-F_4	187.3	165.2	22.1*	172.9	156.3	16.6*	165.3	154.9	10.4
1000-kernel weight	F_2-F_3	187.5	152.1	35.4**	191.6	161.4	30.2**	181.6	150.8	30.8**
	F_3-F_4	172.6	149.6	23.0**	180.5	153.2	27.3**	175.9	152.8	23.1**
Grain yield/plant	F_2-F_3	201.0	153.4	47.6**	198.6	158.3	40.3**	187.7	133.8	53.9**
	F_3-F_4	188.0	148.3	39.7**	189.7	152.8	36.9**	182.5	160.5	22.0**

*and ** Significant differences between high and low groups at the 0.05 and 0.01 probability levels, respectively.

Table 5 shows the highest yielding lines in F_4 population,showing the effectiveness of indirect selection for grain yield *via* yield components as well as direct selection for yield in early generations of selection. Selection for grain yield (HGY) in F_2 and F_3 identified three lines among the best ten lines yielding in each cross. On the other hand, selection for high number of kernels/spike (HKS) resulted in two lines in each cross. Meanwhile, selection for high number of spikes (HSP) resulted in only one superior line in the first and the third cross and two in the second cross. The number of selected high yielding lines based upon kernel weight reflected the superiority of indirect selection for yield *via* kernels weight (HKW) which demonstrated that selection for this trait resulted in four lines in the first and the third cross and three in the second cross and the importance of the balance among yield components. Indirect selection *via* other components was helpful in detecting some other superior lines.

Table (5): Identification of the ten highest yielding F_4 lines derived by selection in F_2 and F_3 in three barley crosses.

Cross 1			Cross 2			Cross 3		
Line	ID	Yield (kg/fed)	Line	ID	Yield (kg/fed)	Line	ID	Yield (kg/fed)
HGY	115	2360	HKW	66	2359	HKW	52	2258
HGY	120	2401	HGY	132	2390	HGY	140	2308
HKW	89	2304	HGY	116	2386	HSP	89	2200
HSP	110	2267	HKW	145	2284	HKW	121	2146
HKW	143	2295	HKS	130	2268	HKW	119	2156
HKW	125	2388	HKW	124	2254	HGY	108	2328
HKW	145	2311	HSP	89	2360	HGY	129	2313
HKS	64	2288	HKS	133	2306	HKS	160	2114
HGY	151	2380	HSP	138	2239	HKW	163	2132
HKS	71	2306	HGY	45	2379	HKS	95	2097

The first letter (H) stand high expression of the trait, SP, KS, KW and GY stands for number of spikes/plant, number of kernels /spike, 1000-kernel weight and grain yield /plant, respectively and the number denotes the F_2 sequence. (Fed. =Feddan = 4200m^2)

In a breeding program, the information for early selection efficiency for grain yield and kernels weight, genotypes are especially important for making decisions dealing with population size and possible selection pressure. This study was directed to investigate the effectiveness of sequential selection for grain yield /plant in early generations and the related response of the other important quantitative characters. These obtained results were supported by high realized heritabilities, high response to selection, and indentifying superior lines in later generations due to selection for some yield components in early generations. Therefore, Gebre-Mariman *et al*. (1988) reported that, the use of early generation data and the analysis of the intergeneration relationships of important traits would be a more practical approach to asses the potential of crosses.

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الاستجابة للانتخاب لمحصول النبات ومكوناته في الأجيال المبكرة لهجن الشعير

السيد حامد الصعيدي

قسم المحاصيل – كلية الزراعة بطنطا – جامعه طنطا

الملخص العربي

تـم إجراء هذا البحث في المواسم ٢٠٠٠/٢٠٠١ ، ٢٠٠١/٢٠٠٢ ، ٢٠٠٢/٢٠٠٣ ولقد حـدث تحسين للتراكيب الوراثية وذلك بالحصول على إنتاجيه أفضل لمحصول الشعير وذلك عن طـريق اسـتخدام طرق التربـية المختلفة وقد أجريت هذه الدراسة لمقارنة فاعلية الانتخاب للأجيال المبكرة سواء الانتخاب المباشر للمحصول أو غـير المباشر لمكونات المحصول وذلك باسـتخدام Fasoulas (1973) honeycomb design وذلك لانتخاب نباتات الجيل الثاني فـي ثـلاث هجن للشعير. وقد استخدم نظامين للاستجابة لعملية الانتخاب وهما: الانتخاب في نـباتات الجـيل الثانـي لزراعة نباتات الجيل الثالث والانتخاب في نباتات الجيل الثالث لزراعة نـباتات الجـيل الـرابع وقد استخدم شدة الانتخاب لـ ٥% من النباتات لكل صفه من الصفات المدروسة على أساس أعلى القيم وكذلك لسلالات الجيل الثالث.

كانـت درجـة التوريث الواقعية (RH) من الانتخاب في الجيل الثالث للجيل الرابع ذات قيمه أعلى لكل من صفتي عدد الحبوب في السنبلة للهجين الأول والثاني وذلك بقيم ٧٣,٣ ، ٨٣,٥ علـى الترتيب وقيمة متوسطة للهجين الثالث ٦٧,٤ وبالنسبة لصفة وزن الألف حبه فقد كانت قيمـتها متوسـطة وتراوحـت مـن (٦١,١-٦٦,١) للهجن الثلاث ثم تلاهما صفه محصول الحبوب للنبات، بينما كانت القيم الأقل لصفة عدد السنابل على النبات للهجن الثلاث- كانت قيم الانـتخاب في الجيل الثالث للجيل الرابع أعلى من الانتخاب في الجيل الثاني للجيل الثالث لصفه المحصـول ومكوناتـه لجمـيع الهجـن، إن القيم المرتفعة للـ (RH) لصفتي عدد الحبوب في السـنبلة ووزن الحبوب أوضحت أن الانتخاب مؤثر لهاتين الصفتين وان الانتخاب غير المباشر لصـفه المحصول تبعاً لهذه الصفات مؤثر وان القيم المنخفضة لصفه عدد السنابل على النبات يكـون الانـتخاب فـيها أقل تأثيرا على صفة محصول النبات وأن صفه وزن الحبوب لها تأثير مباشر على محصول الحبوب في الهجن الثلاثة المدروسة.

لتقليل الاختلاف البيئي لنباتات الجيل الثاني فان الانتخاب للحبوب الأثقل وعدد الحبوب الأكثر تكون مؤثرة على تحسين محصول نبات الشعير.