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Relationships Between F2, F3 and F4-Derived Lines for above Ground Biomass And Harvest Index of Three Barley (*Hordeum vulgare* L.) Crosses in a Mediterranean-Type Environment

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Abstract: F2, F3 and F4-derived lines from 3 barley cross populations were used to investigate whether grain yield could be improved by selecting for above ground biomass and harvest index under semi-arid Mediterranean-type environment. Results indicated, in F2 and in F3, significant and positive correlation between grain yield and plant biomass as well as between grain yield and harvest index. The efficiency of indirect selection in F2 and F3, based on above ground biomass and on harvest index varied among crosses. Indirect selection was not more efficient no more consistent than direct selection for grain yield because of low similarity between early generations and low heritability of the selection criterion. Index selection including grain yield, above ground biomass and harvest index gave encouraging results which need to be confirmed.

Key words: *Hordeum vulgare* L., semi-arid, index, selection efficiency, biomass, mediterranean-type environment

INTRODUCTION

For maximum efficiency and progress in breeding for any character, it would be advantageous if selection could be carried out in early generation. Early generation selection requires to use selection criteria that can be able to identify superior genotypes, must be less subjected to genotype x environment interaction, highly heritable and have good predictive values. Fischer and Kertz (1976) mentioned that harvest index is a best predictor of grain yield in later generations because it is less influenced by environmental changes compared to grain yield. Yield improvement of some recent cultivars has been associated with higher biomass (Waddington *et al*., 1987). In drier environments genotypic capacity to develop sufficient biomass early in the season, when moisture is available, is a desirable characteristic (Ceccarelli *et al*., 1992). High biomass production at maturity has been reported to be positively correlated with grain yield (Turner and Nicolas, 1987). However, Austin *et al*. (1980) found that genetic variation in above ground biomass is usually expressed only in favorable years when it would benefit grain yield. The present contribution aimed to investigate the relationships between F2, F3 and F4 derived lines for plant biomass and harvest index and to determine the relative efficiency of selection based these agronomic traits compared to selection based on grain yield in three barley (*Hordeum vulgare* L.) crosses.

MATERIALS AND METHODS

Three barley crosses were made at the Setif Agricultural Research Station (Algeria). Alpha, a 2-row type barley, was crossed to Tichedrett. Saida was crossed to Jaidor and Aths/Lignée 686 was crossed to Rebelle. Tichedrett and Saida are 2 local 6-row cultivars. Tichedrett has a vernalization requirement than Saida which behaves as a true spring type. Alpha, Jaidor and Rebelle are Europeen cultivars, received kindly from Inra-Ensa Montpellier. Aths/Lignée 686 is an Icarda breeding line. Each F1- hybrid was sown in a single 3-row plot, 3 m long. Seeds were spaced 0.15 m and rows were 0. 30 m apart. F2 populations were grown in a single plot 3 m long ×12 rows, 0. 30 m apart. At maturity, border plants were removed and data recorded on 120 plants. On November, 2004 seed samples from each one of the 120 F2-plant and parental lines were utilized to grow an F3 yield trial with 2 replicates. Plot was one single row of 3 m long per F3-line and 0.20 m apart. Forty seeds were sown per row. Seeds from each one of the 120-F3 lines and parents were used to sow an F4 yield trial, the following year, in a completely randomized block design with three replications. Plot was one single row per F4-line, 3 m long and 0.20 m apart. Data collection in F2 was per plant and on plot basis in F3 and F4 yield trials from a harvested area of 2×0.20 m per replicate. Traits measured were plant height, above ground biomass, grain yield, harvest index and number of days from January 1st to heading (DHE).

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Two selection procedures were investigated. One based on harvest index and the second on plant biomass. They were compared to selection based on grain yield. High and low groups were generated from F2 and F3 populations of each cross by selecting the 10 highest and the 10 lowest entries per selection criterion. Phenotypic correlation coefficients were computed per generation and between generations per cross. Selection differential was calculated as the difference between high and low group means (Wong and Baker, 1986). Selection response was calculated as the difference between high and low group means (Sharma and Smith, 1986). Significance of response to selection was determined from the analysis of variance of the selected groups through a contrast between high vs low group means. Relative selection efficiency (E) was calculated as E = (rg.hx)/hy, with E is the predicted relative selection efficiency of trait x to improve trait y, rg is the genotypic correlation coefficient between traits X and Y, hx and hy are the square root of the heritability of traits x and y (Yu *et al.*, 1993). Kotecha and Zimmerman (1978) heritability in the F2 generation was estimated as:

$$h^2 = [\sigma^2_{F2} - (\sigma^2_{P1} + \sigma_{P2} + 2\sigma^2_{F1})/4]/\sigma^2_{F2}$$

In F3, broad sense heritability was estimated from the analysis of variance mean squares and expressed on mean basis. Regression coefficient of F4 progenies on their respective F3 parents was used as an estimate of narrow sense heritability in the F4 generation. Realized heritability in F4 was calculated as the ratio of response to selection on selection differential (Falconer, 1982). A selection index was intended in F3 with the objective to improve grain yield considering informations from above ground biomass and harvest index (Harding *et al.*, 1987). The equations to be solved to get the index coefficients were:

$$b_1\sigma^2_Y + b_2\, Wr_{X.Y} + b_3\, Wr_{Z.Y} = \sigma^2 g_{.\,Y}$$

$$b_1 Wr_{X.Y} + b_2\, \sigma^2_X + b_3\, Wr_{X.Z} = Wrg_{X.Y}$$

$$b_1 Wr_{Z.Y} + b_2\, Wr_{X.Z} + b_3\, \sigma^2_{\ Z} = Wrg_{Z.Y}$$

where, b_1, b_2 and b_3 are the index coefficients, σ^2_X, σ^2_Y σ^2_Z are the phenotypic variances of the traits Y= grain yield, X = above ground biomass and Z = harvest index; $\sigma^2 g$ is the genotypic variance of trait Y= grain yield, $Wr_{X.Y}$, $Wr_{X.Z}$, $Wr_{Z.Y}$ are the phenotypic covariances between pairs of characters included in the index and Wrg $_{X.Y}$, Wrg $_{Z.Y}$ are the genotypic covariances between grain yield and traits used to improve selection efficiency (Falconer, 1982). The genetic variance ($\sigma^2 g$) was deduced from the analysis of variance of the F3 generation through variance component procedure reported by Comstock and Moll (1963). Phenotypic variance (σ^2) was calculated as the sum of genetic and error variances, $\sigma^2 = \sigma^2 g + \sigma^2 e/r$, with r is the number of replications in the F3 yield trial. Phenotypic (Wr X.Y) and genotypic (Wrg X.Y) covariance's were calculated according to Falconer (1982):

$$Wr = rpXY\sqrt{\sigma^2 X.\sigma^2 Y},$$

rp is the phenotypic correlation coefficient between traits X and Y,

$$Wrg = rgXY.hX.hY\sqrt{\sigma^2 X}\sqrt{\sigma^2 Y}, \text{ rg}$$

is the genotypic correlation coefficient between trait X and trait Y, hx and hY are square root of narrow sense heritability of trait X and trait Y. Variances and covariances were calculated from multivariate analysis of variance of traits included in the index, using standardized data. After solving equations and getting coefficients, the index has the following form

$$I = b1\ XGY + b2\ XBIO + b3\ XHI,$$

where, X stands for mean values of traits indicated as subscripts. Grain yield, above ground biomass and harvest index means of each one of the 120 F3 lines were used to calculate I specific for each line. 10 lines with highest and those with lowest I values were selected in the F3 and their selection response measured in the F4 yield trial.

RESULTS AND DISCUSSION

F 2-phenotypic correlation matrix showed that grain yield was positively related with above ground biomass (r varied from 0.88 to 0.94) and with harvest index (r varied from 0.35 to 0.40), in the three cross populations. Plant height and number of days to heading relationship with grain yield was weak and cross dependent. When statistically significant the correlation coefficient was positive with plant height (r varied from 0.13 ns to 0.34) and negative with the number of days to heading (r varied from -0.04 ns to -0.22). Above ground biomass was significantly correlated with plant height of the three crosses (r varied from 0.32 to 0.43) and negatively correlated with days to heading of Saida/Jaidor (r= -0.18) and Aths/lignée 686//Rebelle (r= -0.26). No significant relationships existed between harvest index and the variables plant height, above ground biomass and number of days to heading. These results suggested that, within the three cross populations studied, selection based on above ground biomass or on harvest index lead to grain yield improvement.

Table 1: Selection differentials (H-L) and means of high (H) group of lines selected for above ground biomass, harvest index and grain yield in the F2-generation of 3 barley crosses

Trait	PHT (cm)		BIO (g/plant)		DHE (days)		HI (%)		GY (g plant^{-1})	
Group	H	H-L	H	H-L	H	H-L	H	H-L	H	H-L
Cross	**Selection for above ground biomass**									
A	81.8	15.1*	128.1	103.3*	119.8	-6.7*	34.1	-1.6 ns	42.5	33.6*
B	85.5	7.0*	99.7	65.3*	126.8	-3.8*	46.2	1.0 ns	45.8	30.2*
C	74.8	4.1*	87.6	65.7*	118.7	-6.2*	45.8	0.3 ns	42.2	31.0*
	Selection for harvest indexA									
A	73.7	-4.7*	71.9	-1.4 ns	123.5	-1.7 ns	53.0	27.3*	35.8	16.9*
B	78.1	-4.6*	67.3	5.7 ns	127.2	1.4 ns	56.0	22.3*	37.9	16,2*
C	72.4	1.1	51.8	4.1 ns	120.8	-0.7 ns	53.9	19.6*	27.9	11.1*
	Selection for grain yieldA									
A	76.2	9.0*	116.5	90.9*	122.0	-1.7 ns	43.0	9.3*	48.2	39.6*
B	84.0	3.5ns	92.6	54.5*	125.0	-3.5*	51.4	8.6*	47.4	32.4*
C	75.3	4.6*	89.4	64.4*	118.1	-5.9*	48.0	6.4*	43.7	33.3*

ns,*: non significant and significant differences at 5% level. A = Alpha/Tichedrett, B = Saida/Jaidor and C= Aths/lignée 686//Rebelle, BIO= above ground biomass, PHT= plant height, DHE= days to heading, HI= harvest index, GY= grain yield

Table 2: 3-Response to F2-selection for above ground biomass, harvest index and grain yield of 3 barley crosses

Trait	PHT(cm)		BIO (g m^{-2})		DHE (days)		HI (%)		GY (g m^{-2})	
Group	H	H-L	H	H-L	H	H-L	H	H-L	H	H-L
Cross	**Selection for above ground biomass**									
Alpha	55.5		979		147.5		44.0		558	
Tichedret	90.0		1197		148.0		41.3		518	
A	83.8	3.0 ns	1903	117*	144.9	-2.4*	45.7	-2.3*	930	88*
Saida	81.0		1690		157.0		40.3		788	
Jaidor	75.0		1587		152.0		45.3		615	
B	84.0	4.0*	1840	219*	149.0	1.0*	45.5	0.1 ns	880	81*
Aths/Lig	52.5	1164		145.0		25.0		359		
Rebelle	77.5		875		155.5		53.0		506	
C	77.2	-5.3*	1591	-73*	146.9	2.9*	46.6	-5.3*	806	43 ns
	Selection for harvest index									
A	87.2	5.0*	1925	190*	144.4	-0.2 ns	43.9	-2.4*	852	48*
B	83.8	7.0*	1846	60 ns	148.2	-1.2*	47.3	2.4*	809	5 ns
C	82.8	-1.7*	1608	-73*	144.2	-0.1 ns	47.0	0.1 ns	770	-6 ns
	Selection for grain yield.									
A	82.8	1.0 ns	1885	242*	145.9	-1.1*	46.0	-3.4*	1006	31*
B	79.2	-1.5 ns	1654	73 ns	147.8	-5.0*	46.5	1.9*	857	26 ns
C	78.0	-3.2 ns	1638	-93*	145.3	0.8 ns	45.9	-6.0*	826	-2 ns

ns, **,**: response non significant and significant at 5 and 1% level respectively. BIO= above ground biomass, PHT= plant height, DHE= days to heading, HI= harvest index, GY= grain yield

Above ground biomass and harvest index selection differentials were positive and significant (Table1). Selection for high plant biomass induced significant changes in grain yield and number of days to heading of the three crosses. Significant and positive changes were observed also for plant height of Alpha/Tichedrett and Saida/Jaidor. Selection for high harvest index values affected significantly grain yield of the 3 crosses. Selection for high grain yield improved both plant biomass and harvest index of the 3 crosses, plant height increased and number of days to heading decreased in Alpha/Tichedrett and Aths/lignée 686//Rebelle crosses (Table 1). Predicted relative selection efficiency varied from 0.18 for Aths/lignée 686//Rebelle to 0.45 for Alpha/Tichedrett when harvest index was the selection criterion and from 0.28 for Aths/lignée 686 //Rebelle to 1.0 for Saida/Jaidor for selection based on plant biomass.

These values indicated that efficiency of selection based on harvest index or on above ground biomass to improve grain yield will be variable and cross dependent F3-response of plant biomass to selection based on above ground biomass was positive and significant in Alpha/Tichedrett and Saïda/ Jaidor but negative in Aths/Lignée 686//Rebelle. Grain yield correlated response was positive and significant when the response of above ground biomass was positive (Table 2). F3-direct response to harvest index selection was significant and positive in Saïda/Jaidor, negative in Alpha/Tichedrett and no significant in Aths/Lignée686//Rebelle. Grain yield correlated response was significant and positive in Alpha/Tichedrett cross and was accompanied by an improvement of plant height and above ground biomass. F3-direct response to grain yield selection was significant and positive in Alpha/Tichedrett population. Grain yield response was followed by significant and positive change in above ground plant biomass. F3-phenotypic correlation indicated that grain yield of the 3 populations was significantly and positively correlated with above ground

Table 3: F4-responses to selection for above ground biomass, harvest index and grain yield in the F2 and F3 generations of 3 barley crosses

Traits	PHT (cm)		BIO (g m^{-2})		DHE (days)		HI (%)		GYF3/F4		(g m^{-2}) GY F2/F4	
Groups	H	H-L	H	H-L	H	H-L	H	H-L	H	H-L	H	H-L
Crosses	**Selection for above ground biomass**											
Alpha	75		1250		113		36		403			
Tiched	95		1100		119		38		425			
A	86	8*	1200	350*	117	8*	35	-8*	421	56*	420	16ns
Saida	87		950		113		35		335			
Jaidor	75		1100	112		40			435			
B	84	7*	1200	450*	117	5*	48	-3ns	508	56*	467	-5.5ns
Aths/L	75		850		112		42		355			
Rebel	90		900		117		38		345			
C	82	12*	950	250*	111	0.0ns	44	2.0ns	332	72*	309	27ns
	Selection for harvest index.											
A	85	4.0ns	1050	50ns	113	5.0*	42	1.0ns	443	40ns	418	13ns
B	84	9.0*	900	50ns	118	1.0ns	48	3.0ns	436	56*	408	-7.0ns
C	74	4.0ns	700	0ns	110	-1.0ns	41	-2.0ns	282	-11.0ns	297	14.0ns
	Selection for grain yield											
A	82	0.0ns	1050	50ns	113	0.0ns	42	0.0ns	448	21.0ns	423	18.5ns
B	85	10.0*	950	150ns	117	7.0*	53	3.0ns	506	72.0*	470	2.0ns
C	72	5.0ns	750	150ns	110	-1.0ns	46	6.0*	388	118*	269	-25.0ns
	Index selection = 0.001GY+ 0.26BIO + 0.13HI											
A	82.5	0.6ns	1290	230*	111.7	-1.6ns	41.0	2.3ns	523	107.0*		
B	83.6	8.0*	1220	270*	106	5.0*	48.9	1.8ns	597	148.0*		
C	73.4	1.7ns	840	210*	110.6	0.2ns	40.0	0.5ns	320	66.0*		

ns, **,**: response non significant and significant at the 5 and 1% level respectively, BIO= above ground biomass. (kg m^{-2}), PHT= plant height, DHE= days to heading, HI= harvest index, GY= grain yield (g m^{-2})

biomass (r varied from 0.84-0.91), with plant height (r varied from 0.43 to 0.49) and with harvest index (r varied from 0.22-0.27) but showed no relationship with the number of days to heading. Above ground biomass was positively correlated with plant height (r varied from 0.42-0.50), but harvest index showed no consistent relationships with the measured characters. These relationships were similar to the one observed in the F2-generation.

F3-predicted relative selection efficiency varied from 0.69 for Alpha/Tichedrett to 0.84 for Aths/ lignée 686//Rebelle for selection based on harvest index and from 0.87 for Aths/lignée 686 //Rebelle to 1.45 for Saida/Jaidor for selection based on above ground biomass. Selection differential of above ground biomass was accompanied by positive change in grain yield. Harvest index selection differential was associated with negative change in above ground biomass and positive change in grain yield. Grain yield selection differential was associated with positive change in plant height, above ground biomass and harvest index (data not shown). F4-grain yield correlated responses to selection made in F2 for above ground biomass, harvest index and for grain yield were not significant (Table 3). F4-response of biomass to F3 selection based on above ground biomass was significant in 2 crosses with grain yield correlated responses positive in the 3 crosses. Harvest index decreased but plant height increased in the three populations and number of days to heading increased in response to this selection in Alpha/ Tichedrett and Saida/Jaidor populations only (Table 3). No cross showed significant response to selection for harvest index. Grain yield response to selection for grain yield was significant in two crosses. Positive grain yield response was associated with positive change in plant height in Saida/Jaidor.

Selection differential of index selection was positive and significant for grain yield and above ground biomass but not for harvest index in F3-generation (Table 3).The observed responses, in the F4 generation, of above ground biomass and grain yield were positive and significant in the 3 populations studied but response of harvest index to index selection was non significant. This indicated that multi-traits selection might be a worthwhile procedure to improve simultaneously desirable traits in one genetic background. The observed variation in grain yield responses to early generation selection indicated that harvest index and above ground biomass were not more efficient nor more consistent as selection criterion than grain yield.

This inefficiency could be due to the weak relationships between generations for the measured characters, since inter-generation correlation coefficients between F2/F3 and F2/F4 were low in magnitude and often non significant. For above ground biomass r F2/F4 varied from 0.01-0.14 ns and from 0.32-0.34 between F3 and F4. For harvest index r F2/F4 varied from 0.03 to 0.12 ns and from 0.02 ns to 0.23 between F3 and F4. For grain yield, r F2/F4 varied from 0.01-0.17 ns and from 0.21-0.23 between F3 and F4. Better relationships existed between generations for plant height (r varied from 0.24-0.34 for F2/F4 and from 0.44-0.57 for F3/F4) and days to heading (r varied from 0.31-0.39 for F2/F4 and from 0.32-0.44 for F3/F4). Broad sense Heritability averaged over the 3 populations was 67% for above ground biomass, 54% for harvest index and 45% for grain yield. Narrow sense Heritability averaged over the 3 F3-populations was 23% for above ground biomass, 13% for harvest index and 20% for grain yield. These values improved slightly in the F4 generation since they were 36, 34 and 30%, respectively for biomass, harvest index and grain yield. Realized heritability varied from zero to 0.38 for the mentioned traits.

Genotype x environment interactions were involved since close relationships between grain yield and the selection criteria existed within F2 and F3 generations, but low similarity was observed between generations for the measured traits. Variation of non selected traits in response to environmental stimuli had important effects which diluted selection responses. Phenology is an important adaptative trait under semi-arid Mediterranean conditions, where late frost and terminal heat and drought affect differentially yield components and growth parameters. Early material is damaged by late spring frost and late one is usually hampered by heat and drought stress. Under drought conditions plant height contributes substantially to above ground biomass formation and so to grain yield while under non droughty conditions this contribution is less pronounced.

Although, Donald and Hamblin (1976) suggested the use of plant biomass and harvest index as early generation selection criteria, our results are in agreement with those reported by Roseille and Frey (1975), who found that indirect selection for grain yield through harvest index was not efficient. Sharma and Smith (1986) reported also a lack of correlated response of grain yield to selection for harvest index in 3 winter wheat populations and attributed this inefficiency to low genetic correlation between grain yield and harvest index. In fact, selection for one trait to increase or stabilize grain yield is dependent on the extent of compensatory effect in the other characters determined by environment and genetic background. One trait might be successful as a selection criterion for yield potential in similar plant type with equal productivity but fails when different plant types of varying productivity are present in the base population in which selection is practiced (Mc Vetty and Evans, 1980). The effectiveness of early generation testing is influenced by genotype x environment interactions, low heritability and by inter-genotypic competition among individuals within a selected heterogeneous line (Gedge *et al.*, 1978).

CONCLUSION

In semi-arid Mediterranean-type environment, a short growing season coupled with low temperatures during winter and high temperatures and rising evaporative demand in the spring as rainfall is declining, results in low grain yield due to genotypic inability to produce sufficient dry matter at maturity. It seems interesting to incorporate into barley germplasm specific characters like the ability to produce high biomass early in the cycle, to improve its adaptability to environmental constraints. Results of this investigation indicated however that indirect selection to improve grain yield through above ground biomass or harvest index was not sufficiently efficient to warrant the extra effort required to measure plant biomass and harvest index at maturity on several breeding lines. But above ground biomass and harvest index may serve as means of identifying physiologically valuable genotypes in terms of their assimilate partitioning ability and their water use efficiency, characteristics which become helpful under semi-arid conditions to avoid crop failure. Index selection based on these characters and grain yield may culminate in the identification of good germplasm which can be used in crossing to develop more adapted genotypes capable of relatively high grain yield and acceptable production stability.

REFERENCES

Allard, R.W., 1960. Principles of plant breeding. Longman Group N.Y., pp: 420.

Austin, R.B., J. Bingham, R.D. Blackwell, L.T.R. Evans, M.A. Ford, C.L. Morgan and M. Taylor, 1980. Genetic improvement in winter wheat yield since, 1900. and associated physiological changes. J. Agric. Sci., 94: 675-689.

Benmahammed, A., 1995. Corrélations et héritabilités de quelques caractères à variation continue chez l'orge (Hordeum vulgare L). MS Thesis ENS A Alger., pp: 70.

Cantero-Martinez C., J.L. Villar, I. Romagosa and E. Fereres, 1995. Growth and yield responses of 2 contrasting barley cultivars in a Mediterranean environment. Eur. J. Agron., 4: 326-330.

Ceccarelli, S., S. Grando and J. Hamblin, 1992. Relationship between barley grain yield measured in low and high-yielding environments. Euphytica, 64: 49-58.

Comstock, R.E. and R.H. Moll, 1963. Genotype x Environment Interactions. In: Hanson W.D. and H.F. Robinson (Eds.). Statistical Genetics and Plant Breeding, NAS-NRC. 982, Washington D.C., pp: 164-169.

Donald, C.M. and J. Hamblin, 1976. The biological yield and harvest index of cereals as agronomic and plant breeding criteria. Adv. Agron., 28: 361-411.

Falconer, D.S., 1982. Introduction to quantitative genetic. Eds. Longman Group limited New York.

Fischer, R.A. and Z. kertz, 1976. Harvest index in spaced population and grain weight in microplots as indicators of yielding ability in spring wheat. Crop Sci., 16: 55-59.

Gedge, D.L., W.R. Fehr and D.F. Cox, 1978. Influence of inter-genotypic competition on seed yield of heterogeneous soybean lines. Crop Sci., 18: 233-236.

Harding, J., T. Byrne and D. Drennan, 1987. The use of a selection index to improve gerber cut-flowers. Acta Horticulturae, 205: 64-68.

Kotecha, A. and L.H. Zimmerman, 1978. Inheritance of seed weight, pappus and striped hull in safflower species. Crop Sci., 18: 959-1002.

Kumar, J., 1975. Comparison of early generations yield testing and SSD procedure in wheat breeding. Crop Sci., 15: 295-299.

Mc Vetty, P.B.E. and L.E. Evans, 1980. Breeding methodology in wheat. I. Determination of characters measured on F2 spaced plants for yield selection in spring wheat. Crop Sci., 20: 583-586.

Roseille, A.A. and K.J. Frey, 1975. Estimates of selection parameters associated with harvest index in Oat lines derived from a bulk population. Euphytica, 24: 121-131.

Rousset, M., 1985. L'élaboration du rendement chez les blés hybrides en comparaison avec les parents. INRAF CR., pp: 311-333.

Sharma, R.C. and E.L. Smith, 1986. Selection for high and low harvest index in winter wheat populations. Crop Sci., 26: 1147-1150.

Turner, N.C. and M.E. Nicolas, 1987. Drought resistance of wheat for light textured soils in Mediterranean climate. In: Drought tolerance in winter cereals. Srivastava, J.P., E. Porceddu, E. Acevedo and S. Verma, Eds., pp: 203-216.

Waddington, S.R., M. Osmanzai, M. Yoshida and J.K. Ransom, 1987. The yield of durum wheat released in Mexico between, 1960 and 1984. J. Agric. Sci., 108: 469-477.

Westcott, B., 1979. Early generation selection in a cross of spring barley. Z. Pftanzenzucht, 83: 64-80.

Wong, L.S.L. and R.J. Baker, 1986. Selection for time to maturity in spring wheat. Crop Sci., 26: 1171-1175.

Yu, Y., J. Harding and T. Byrne, 1993. Quantitative genetic analysis of flowering time in the Davis Population of gerbera. Euphytica, 70: 97-103.