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Earliness and Yielding Ability of Selected Barley (*Hordeum vulgare* L.) Doubled Haploid Lines Based on Field Performance

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Abstract

Earliness is an important factor in adapting barley genotypes to different cultivation regions and growing seasons, and consequently for maximizing crop yield. Therefore, breeding early-maturing genotypes is a major purpose in barley breeding programs. Keeping in view this objective, doubled haploid (DH) lines derived from crossing barley cultivars presently used in Europe and West Asia were tested for earliness and yield traits during two consecutive seasons. Results demonstrated significant differences among barley lines with a wide spectrum of earliness ranging from early-maturity to late-maturity, which were consistent in both seasons. Interestingly, 12 derived DH lines had slightly early -maturity (128 - 135 days to heading**)** than the mean of the parents (142-151 days). Some weak but significant correlation (r =0.40, P<0.01) was found between the short maturity periods and grain yield, indicating that identification of early-maturing and high-yielding traits in the same lines is possible. Hence, in environments with cool growing seasons, the newly identified DH lines with short-maturity period and high yielding can be potential donors in the breeding program to produce new commercial barley genotypes.

Keywords: Barley (*Hordeum vulgare* L.), earliness, yield, doubled haploids

1. Introduction

Barley (*Hordeum vulgare* L.) is one of the most important crops from an economic point of view and can be successfully grown in a broad range of environments [1]. Therefore, its yield can be increased through the development new cultivars which better adapt under adverse conditions, resist to biotic and abiotic stresses [2]. Hence, barley breeding is focusing on the creation of genetic variability and applying suitable selection procedures for improving the desirable traits [3].

In recent years, earliness (heading date) of barley has been widely studied and highly connected with environmental adaptation and yield. This trait has a complex genetic architecture that makes it very important in barley breeding programs, since, new early maturity cultivars are desirable, because of their ability to survive under harsh conditions during the growing season [4].

Under Mediterranean conditions, escaping barley from drought, heat stress and pests stresses can be attained by shortening its growing cycle [5], therefore, reduced heading date cultivars might be enhanced and adapted to high yield environments [6].

Earliness and yield are complex traits, which are inherited by polygenic inheritance [7], thus selection of the advanced hybrids for these characters can be possible to perform when information about the interaction between genotype and environment is available. However, successful breeding programs require continuous information regarding the genetic variation and systems governing earliness attributes, in addition to grain yield and its components [8].

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On the other hand, production of high yielding lines via crossing of parents is considered to be a difficult and long method. Therefore, doubled haploid (DH) production through anther culture technique can speed up the breeding cycle by decreasing the requested time for attaining homozygosity [9]. In fact, production of DH method has proved to be a very helpful tool for producing high yielding homozygous cereal genotypes during a short time [10].

This present work was carried out to screen barley DH lines with short-maturity period and high yielding through four crosses of barley cultivars presently grown in Europe and West Asia under Syrian field conditions which are typical of Mediterranean environments. The relationship between early- maturing and high-yielding DH lines was also investigated.

2. Materials and methods

Barley material. A total of 40 DH barley lines through anther culture created according to Kasha and Kao [11], were selected based on their agronomic traits and evaluated in the current work. Four crosses were made between six barley parents currently used in Europe and West Asia (Table 1). Briefly, spikes were manually emasculated and pollinated with fresh pollen. Next, they were treated with 2,4-dichlorophenoxyacetic acid (2,4-D). Tillers from F1 plants were collected at mid- to late-uninucleate phase of microspores maturity and reserved in the dark for 21 days under 4 °C in Hoagland's solution. Then, they were washed by ethanol (96 %) and anthers were transferred to FW culture medium. Plantlets were vernalized for 8 weeks and treated with colchicine solution to stimulate chromosome doubling [12].

Field trials. Experiments were performed under natural rainfed conditions (250 mm annual rainfall) approximately 55 km south of Damascus for two growing seasons. Seeds were grown in five rows 1 m long with 25 cm apart (50 seeds per row).

arents and their lines were evaluated in a randomized complete block design with three replications. Earliness was defined as the period between the sowing date and heading date in DH lines and parental plants. It was determined according to Zadoks et al. [13] where, heading stage is the appearance/emergence of the spike out of the flag leaf sheath.

Data analysis. Analysis of variance of earliness and yield of barley genotypes was evaluated using the STAT-ITCF statistical programme (2nd *version*). Differences between means were evaluated for significance by using Newman-Keuls test at 5% probability level, and the relationship between earliness and yield was examined using STAT-ITCF program [14].

3. Results and discussions

In this investigation, six barley parents presently grown in Europe and West Asia were used for screening early - maturing and high-yielding barley DH lines. They were classified as early and late according to the large differences between their heading dates in all experiments. The average heading dates and the mean values of grain yield for parental parents are presented in Table 1. Data showed heading dates averages differed significantly among the parents, and their progenies with a broad spectrum of heading dates ranging from early-maturity to late-maturity, which were consistent in both growing seasons (Table 1; Fig. 1). Twelve early – maturing DH lines were slightly earlier (128-135 days) than the mean of the six parents (142-151 days), and the population of crosses Arabi Abiad/IC-9 will be used for mapping genes associated with slightly early – maturity and high yield, since, some DH lines from this cross were recovered with these both traits (Table 1). These lines will be tested in multilocation experiments to be sure about their stability and adaptability.

On the other hand, some the DH lines (B08-AS-2, 4, 32 and 37) with short maturity periods had higher grain yields (15 g/plant) with weak but significant correlation (r =0.40, P<0.01) between the short maturity periods and grain yield (Fig. 2). However, this might indicate that the early genotypes performed best in terms of grain yield and encouraging selection of early plant material. This weak correlation could be attributed to the modifying effect of the environment which reduced the genotypic variation of the number of days to heading [15].

The results of the present study indicate that 12 DH lines out of 40 progenies had slightly early -maturity than the parents, which could be considered as a possible donor in further breeding programs.

However, heading date in barley has been reported to be related to vernalization, photoperiod and earliness *per se* genes [6]. It has been documented also that the majority of the differences in developmental rates can be attributed to the vernalization and photoperiod response genes, with noteworthy effects of earliness per se alleles [16]. However, quantitative trait loci (QTLs) associated with heading date have been mapped on all barley chromosomes [17], and several allele-specific markers for some candidate genes controlling this trait are identified [18, 19].

Table 1. Barley parents charaters used in this study

Parents	Origin	Type	Days to heading (Day)	Yield (g/plant)
Arrivate	USA	6	151a*	9.3 b
Arabi Abiad	Syria	2	143b	8.6b
PK30-136	Pakistan	6	148a	12.4a
IC-9	ICARDA	6	147a	13.2a
Igri	Germany	2	142b	8.44b
CI5791	Ethiopia	2	146b	6.11c

*Values within a column followed by different letters are significantly different at $P<0.05$ according to Newman-Keuls test.
ICARDA: International Center for Agricultural Research in the Dry Areas

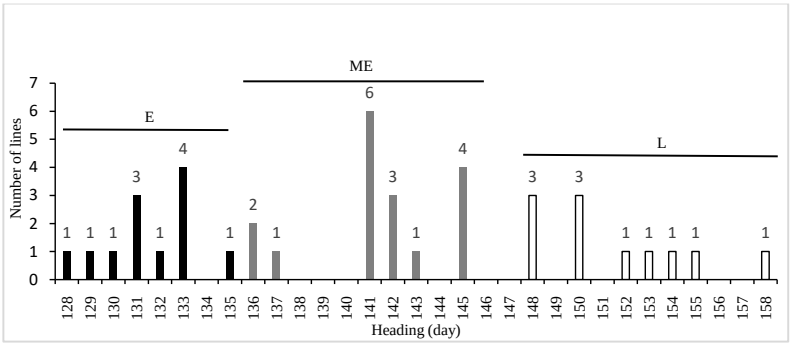

Figure 1. Histograms of heading day in barley DH lines derived in this work E: early, ME; moderately early and L:Late

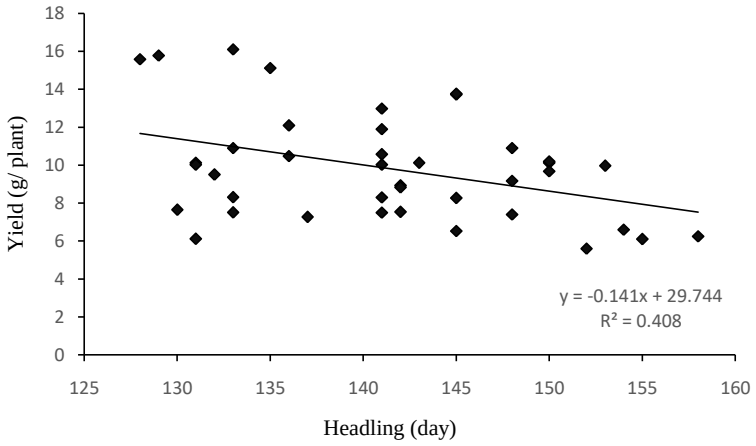

Figure 2. Relationship between heading day and yield of barley DH lines derived in this work

Table 2. Heading days and yield of 40 barley DH lines under field conditions

Cross	No.	Lines	Days to heading	Yield (g/plant)
Arabi Abiad X IC-9	1	B08-AS-1	131f	6.11 e
	2	B08-AS-2	128f	15.58a
	3	B08-AS-3	130f	7.65cd
	4	B08-AS-4	131f	10.13bcd
	5	B08-AS-5	141d	12.98bcd
	6	B08-AS-6	136e	12.09bcd
	7	B08-AS-7	141d	11.9bcd
	8	B08-AS-8	148b	7.40d
	9	B08-AS-9	141d	10.57bcd
	10	B08-AS-10	136e	10.48bcd
	11	B08-AS-11	137e	7.27d
	12	B08-AS-12	150b	10.12bcd
	13	B08-AS-13	148b	10.9bcd
	14	B08-AS-14	131f	10.02bcd
	15	B08-AS-15	132f	9.5bcd
Arrivate X PK30-136	16	B08-AS-16	153a	9.97bcd
	17	B08-AS-17	150b	10.20bcd
	18	B08-AS-18	150b	9.68bcd
	19	B08-AS-19	141d	10.02bcd
	20	B08-AS-20	133e	16.10a
	21	B08-AS-21	142d	8.93bcd
	22	B08-AS-22	141d	7.50cd
	23	B08-AS-23	142d	8.83bcd
	24	B08-AS-24	145c	8.27bcd
	25	B08-AS-25	152b	8.03bcd
	26	B08-AS-26	133d	8.31bcd
	27	B08-AS-27	141d	8.30bcd
	28	B08-AS-28	142d	7.53cd
	29	B08-AS-29	145c	13.72bcd
	30	B08-AS-30	145c	13.77bcd
	31	B08-AS-31	143c	10.12 bcd
	32	B08-AS-32	133e	10.9bcd
	33	B08-AS-33	145c	6.53 ef
CI5791 X Igri	34	B08-AS-34	148b	9.17bcd
	35	B08-AS-35	129f	15.78a
	36	B08-AS-36	133e	7.51cd
	37	B08-AS-37	135d	15.12 a
Arabi Abiad X Arrivate	38	B08-AS-38	154a	6.60 ef
	39	B08-AS-39	158a	6.15 e
	40	B08-AS-40	155a	6.10 e

*Values within a column followed by different letters are significantly different at $P<0.05$ according to Newman-Keuls test.

Selection early barley lines is a main breeding goal to escape droughts periods, which under certain environments such Mediterranean climates might seriously induce crop yield losses [5]. In addition, in barley region of origin, it germinates in the fall season and stays in the vegetative phase during winter, and with increased day length in the spring activates the onset of flowering and the plants mature at the beginning of the dry summer time ensuring a period of seeds dormancy under summer season [20].

This work has provided barley development programs with 12 promising early - maturing DH derived lines that could be considered as possible donors in further breeding programs.

Some weak but significant correlation (r =0.40, $P<0.01$) was found between the short maturity periods and grain yield, indicating that identification of early-maturing and high-yielding traits in the same lines is possible. Hence, it is reasonable to assume that barley grain yield, under Mediterranean conditions, could be increased by selecting early maturity genotypes.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human or animal subjects (if exist) respect the specific regulation and standards.

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