



Response of Hulless barley yield and yield components to different plant densities

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Abstract

This experiment was conducted at agricultural researches and natural resources station of Ardabil in 2013-2014 crop years. The purpose of this test is to evaluate the effect of different plant densities on yield and yield related traits in hulless barley (naked) and determine the yield of these cultivars. The experiment was carried out as a factorial experiment in a randomized complete block design with three replications. Three hulless barley varieties encompasses Lout, EH-87-4 and EH-87-12 and plant densities of 250, 350 and 450 plants per square meter were considered as experimental factors. Analysis of variance showed that effects of varieties and plant densities on number of fertile-tillers per plant, 1000- Grain weight and harvest index was significant. Interaction effects of genotype \times plant density on number of fertile tillers per plant, number of grains per spikeseed yield and biological yield were significant. Treatment combination EH-87-12 variety at plant density of 350 plants/m² was led to maximum number of grains per spike (39.81 No) and minimum value of this attribute (25.59 kernels per spike) was obtained from this variety in plant density of 250 plants/m². The highest 1000-grains weight (46.34 g) was belonged to the EH-87-4 variety and the lowest value was from Lout variety (37.45 g). 1000- Grain weight per 350 plants/m² density was lowest value (38.89 g). Lout variety had the lowest HI (48.42 %) among naked barley varieties on was studied in this experiment. Maximum plant density also led to the highest harvest index. In term of biological yield, different treatments combinations were divided into two separate Statistical groups. So that treatment combinations Eh-87-4 in all plant densities with EH-87-12 variety in two plant density of 350 and 450 plant /m² had the highest biological yield and lout variety in all plant densities with EH-87-12 variety in plant density of 250 plant /m² had the lowest biological yield. Interaction effects variety \times plant density was showed that the best treated combination to improve grain yield was EH-87-4 variety at 450 plant/m² density (7444.7 kg/ha) and treated combinations Lout variety at 250 and 350 plant/m² density had lowest grain yield (4389.0 and 4416.7 kg/ha, respectively).

Keywords: Hulless Barley (Naked), Plant Density, Variety, Yield

INTRODUCTION

Barley is classified into two hull-less barley (*Hordeum vulgare*, L. Subsp. Vulgare) or hulled barley . Culture of hull-less barley is as old as culture of the hulled barley but it has been less studied in the conducted studies in the global level [1]. The absence of hull in barley has considerable effects on physical and chemical characteristics of its grain so that it has less fiber than the hulled barley and even Red Spring Wheat. This reduction of fiber increases energy in hull-less barley metabolism in feeding of birds. Protein rate of the hull-less barley is close to protein rate of wheat while essential amino acids particularly lysine are more than corn and other cereals [2] *Hordeum vulgare* L is also known as hull-less barley, open seed barley, Mohammadi barley, Peighambari barley, Makeh barley and Sour barley[3] considering nutritional value of *Hordeum vulgare* L in feeding of birds and production of this crop in the country, it can be very important to replace it with *Zea mays* L.. Selection of suitable density of the plant should be based on plant factors such as size of plant, tillering, weeding and environmental factors such as sunshine and soil fertility and limitations resulting from these factors reduce desirable density for maximum production [4]. Lopez-Bellido et al., [5] believe

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that attempt should be made to specify density of plant by performing tests to achieve optimal production level in any region. Plant density varies with change of factors such as difference of region, date of cultivation, climatic conditions (particularly rainfall distribution), soil type and cultivars [6]. Suitable density and balanced distribution of plants in surface area led to better use of humidity, food and light and increased yield [4] Most studies on effect of density on yield of plants show that yield increases to average densities and then remains fixed and will considerably decrease only in very high densities [7] It has been reported that variations in different plant densities can be effective in speed of growth of crop and final grain yield [8] Grain yield in barley is regarded as complex trait which is directly or indirectly affected by genes in plant [9]. Bavar [10] reported that increase in density increased the number of spike in *Hordeum vulgare* L.(hull-less barley) in m² while increase of the density reduced the number of grain in spike and 1000 grain weight. Increase in 1000 grain weight due to increase of plant density can be due to reduction of the number of grain and then reduction of competition for receiving photosynthetic materials and transfer or more photosynthetic materials to grain and finally increase of grain weight [11] Increase in plant density due to increase of biological yield compared with grain yield (economic) causes descending trend of harvest index [12] The study conducted on 10 genotypes of *Hordeum vulgare* L.(hull-less barley) in different densities showed that there was statistically significant difference between yield and yield components of grain and effect of genotype and density on traits of grain yield and harvest index was statistically significant [13] MirzaMasoum Nejad et al. [14] reported that different plant densities had significant effect on fertile tiller number, the number of seed per spike, grain yield, harvest index of Alvand cultivar but its effect on 1000 grain weight was insignificant. In study by Dashti Nejad et al. [15] , the highest grain, biological yield, the number of grain per surface area and 1000 grain weight belonging to 10th global barley cultivar with density of 550 plants per m². In tests performed by Thompson et al. [16] on hull-less barley , it was concluded that plant density of 480 to 520 plants per m² was suitable for places with high production potential (more than 5 tons per hectare). Farnia et al [17] reported that Victory barley cultivar in plant density of 350 plants per m² had proper growth due to suitable distribution of stems and leaves in absorption of suitable values of radiation and produced the highest grain yield. Noworolnik [18] using different plant densities for two-year test on different cultivars of barley declared that grain yield of all barley cultivars considerably increased with increasing plant density from 250 to 450 leading to increase of fertile tiller number.

MATERIAL AND METHODS

This test was conducted in Ardabil Agricultural and Natural Resources Research Station (with height of 1350 m, latitude of 38⁰ and 15' and longitude of 48⁰ and 15' and average annual rainfall of 280-300 mm) in 10 km of east of Ardabil(Aralelo) in agricultural year of 2014. Based on meteorological statistics, atmospheric conditions in agricultural season in agricultural year of 2012-2014 in Ardabil Agricultural and Natural Resources Research Station were based on Table 1. Test was conducted as randomized complete block design with three replications. Hull-less barley (*Hordeum vulgare* L) included Lout, EH-87-4 and EH-87-12 and plant densities of 250, 350 and 450 plants per m² as experimental factors. In the related farmland, common agricultural operations such as land preparation, distribution of fertilizer, disc, leveler and furrowing were done with special seeder (Winter Schweinsteiger). Fertilizer rate included 100 kg per hectare of ammonium phosphate as base, 150 kg per hectare of urea fertilizer as base and surplus. Cultivation date was done in February. At time of cultivation, the desired density was created in plots. Each plot was 1.2 m². The consumed seed rate was based on the experimental treatments. To measure yield components and agricultural traits of the studied cultivars in different plant densities after treating the plants, 10 plants were randomly pruned from the middle rows of each plot and the desired traits such as fertile tiller number per plant, number of seed in spike and 1000 grain weight were determined. To determine grain yield,

biological yield was performed from the middle rows of each plot with plant harvest area of 1m² and the above traits were measured after drying. To determine harvest index, the following relation was used.

$$100 \times (\text{biological yield or biomass}) / (\text{economic yield or grain}) = \text{harvest index}$$

For statistical analysis, the obtained data was studied first in terms of normality. For this purpose, Kolmogorov–Smirnov test was used. The applicable software for this purpose was SPSS. ANOVA was performed for the measured traits based on factorial test as randomized complete block design with three replications with SPSS software. Means of the traits were compared with Duncan multiple range test in probability level of 5%. To draw diagrams, Excel software was used.

Table 1- Rainfall and ambient temperature in agricultural season since cultivation (February) to harvesting (June)

Total sunshine	Relative humidity (percent)	Average temperatures (Celsius)	Month Rainfall (mm)	Month
210/1	66	13	6/3	October
127/2	79	6/6	36/2	November
140/8	76	0/9	45/5	December
157/2	80	-4/7	0/6	January
197/6	71	3/8	14/8	February
141/1	72	9/4	25/5	March
207/3	64	7/6	9/3	April
251/9	61	15/3	35/4	May
283/5	61	17/8	24/5	June
287/4	67	19/4	12/2	July

RESULTS AND DISCUSSION

Fertile tiller number per plant

Results of ANOVA indicated significant effect of the cultivar and plant density on trait of the fertile tiller number per plant. Effect of these two experimental factors in probability level of 5% on this trait was significant (Table 2). Mean comparison of the interaction of the test treatments showed that EH-87-12 along with EH-87-4 cultivar caused the maximum number of fertile tiller per plant in plant density of 350 plants per m² without statistically significant difference (with 2.74 and 2.73 tillers per plant) (Diagram 1). Mirza Masoum Nejad et al. [14] reported that different plant densities had significant effect on the fertile tiller number per plant in Alvand cultivar. Bavar [10] reported that increase of density increased spike number in *Hordeum vulgare* L (hull-less barley) in m². In normal conditions, about 70% of the grain yield was gained from tillers. Tilling enables plant to adapt top different conditions. Although few tillers are produced under limited growth conditions, potential of seed production increases in suitable condition when many tillers are produced [19] In this test, low number of fertile tiller per plant in Lout cultivar under different plant densities can be due to low genetic power of this cultivar for production of fertile tiller under different conditions. On the other hand, low rate in two EH-87-4 and EH-87-12 cultivars in low plant density can be related to unsuitable plant density for growth of these two cultivars.

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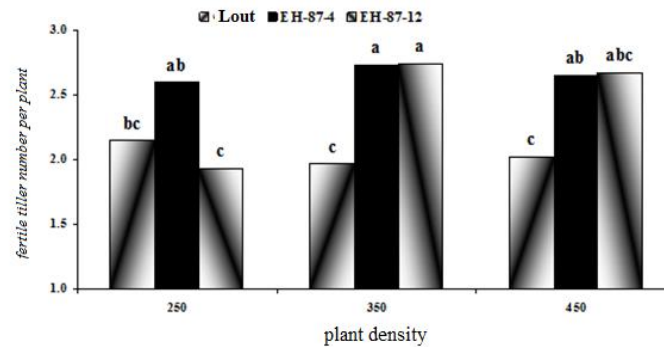


Diagram 1- mean comparison of interaction of cultivar × density on trait of fertile tiller number per plant

Number of seed in spike

Based on results of ANOVA, effect of cultivar and plant density on trait of grain number per spike was significant. Interaction of these two experimental factors on this trait became significant in probability level of 5% (Table 2). Mean comparison of interaction of experimental treatments showed that treatments of EH-87-12 in plant density of 350 plants per m² caused the maximum number of seed per spike (39.81) and the lowest rate of this trait (25.59 seeds per spike) was obtained from this cultivar in plant density of 250 plants per m² (diagram 2). In Durum wheat cultivars, it was concluded that density of 400 plants in m² due to plant distribution and suitable penetration of light into canopy could increase productivity of sunlight and increased the number of seed in spike [20]. Lak et al [21] showed that effect of genotype and density on the number of seed in barley spike became significant. In test performed by Soleimani et al [22], application of more seed reduced the number of seed in spike but increased the number of spike in surface area (fertile tiller). It was concluded that feature of relative competition among the yield components of barley could minimize yield deficiency when a component had decreased. The number of seed per spike is one of the most important components of grain yield and highness of this trait can have positive effect on final yield. In this test, it was specified that EH-87-12 cultivar produced the highest number of seed in spike in desirable plant density (350 to 450 plants in m²).

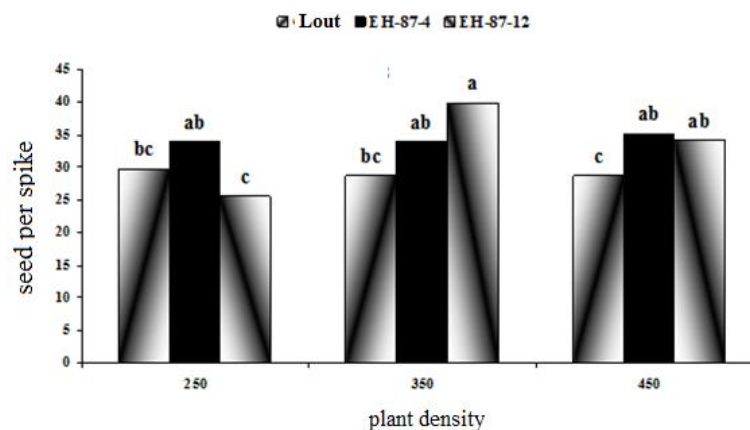


Diagram 2- Mean comparison of interaction of cultivar × density on trait of seed per spike

1000 grain weight

Based on results of ANOVA, effect of cultivar and plant density on trait of 1000 grain weight became significant in probability level of 5% but interaction of these two factors on it was insignificant (Table 2). Means comparison showed that the highest 1000 grain weight (46.34 g) belonged to EH-87-4 cultivar and the lowest rate was obtained from Lot cultivar (37.45g) (Table 3). Among different plant densities, the highest 1000 grain weight was obtained from plant density of 450 plants per m² while the minimum rate of this trait (38.89 g) belonged to plant density of 350 plants (Table 3). Valerio et al. [23] mentioned that both plant density and

genotype and also the conditions in which genotypes were placed showed effective role. In study by Dashti Nejad et al. (2014), the highest 1000 grain weight belonged to 10th global cultivar with density of 550 plants per m². Bavar [10] reported that 1000 grain weight was reduced in *Hordeum vulgare* L with increasing density which was contradictory with results of this test. Some researchers [11 and 24] believe that increase of 1000 grain weight due to increase of plant density can be due to reduction of the number of grain and reduction of competition for receiving photosynthetic materials and transferring more photosynthetic materials to grain and finally increase of grain weight.

Grain yield

Based on results of ANOVA, trait of grain yield was affected by plant density. Interaction of these two factors showed significant difference in probability level of 1% on this trait (Table 2). The best treatment was EH-87-4 in plant density of 450 plants per m² so that it caused the highest grain yield (7444.7 kg/H). Treatment of Lot cultivar in plant densities of 250 and 350 plants per m² without statistically significant difference had the lowest grain yield (with yields of 4389.0 and 4416.7 kg/H) (Diagram 3). In desirable density, suitable plant distribution and better light penetration into canopy caused better productivity of light and improvement of components involved in performance produced the highest grain yield [20] Valerio et al. [23] believe that plant density should be considered based on tilling potential and cultivation place to achieve the highest grain yield. According to results of this test, Baloochi et al [13] reported that interaction between hull-less barley genotypes and plant density in grain yield became significant. In study by Dashti Nejad et al [15] the highest grain yield belonged to 10th global cultivar with density of 550 plants per m².

Table 2- ANOVA of the studied traits in *Hordeum vulgare* L cultivars under different plant densities

S.O.V	Degree of freedom	Mean of square				
		Number of seed in spike	1000 grain weight	Grain yield	Harvest index	Biological yield
Rep	2	31.529	15.658	114.45	1.668	710.77
Cultivar (a)	2	67.756*	178.629*	14882.24**	32.684**	40396.11*
plant density (b)	2	45.082*	97.461*	2484.96**	24.483**	5067.93*
A × B	4	55.493*	21.185ns	1375.16**	3.383ns	5409.12*
Error	15	14.252	34.411	78.72	3.751	346.35
C.V%		11.74	14.14	4.67	3.84	4.97

ns, * and ** are insignificant and significant in probability level of 5% and 1% , respectively.

Table 3- Mean comparison of main effects of cultivar and plant density on the studied traits in *Hordeum vulgare* L

Biological yield	Harvest index	Grain yield	1000 grain weight	Number of seed in spike	Factor
					cultivar
9551.7 c	48.42 b	4620.6 c	37.45 b	29.09 b	Lout
13728.1 a	52.22 a	4166.6 a	46.34 a	34.26 a	EH-87-4
12295.3 b	50.53 a	6208.4 b	42.47 ab	33.15 a	EH-87-12
					plant density
10981.3 b	49.23 b	5425.9 c	41.91 ab	29.72 b	250 plants per m2
12236.3 a	49.66 b	6111.1 b	38.89 b	34.13 a	250 plants per m2
12321.5 a	52.28 a	6458.4 a	45.46 a	32.61 ab	250 plants per m2

Common letters in each column mean lack of significant difference in probability level of 5% with Duncan test.

In this test, Lout cultivar had low yield in all three plant densities (genetic characteristics). Increase of plant density enhanced yield of EH-87-12 cultivar and EH-87-4 cultivar had higher yield in all three plant densities. This cultivar had higher values in terms of fertile tiller number per plant, number of grain per spike and 1000 grain weight than two Lout cultivar and EH-87-

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12 cultivar. In other words, traits involved in yield improved and increased yield of the said cultivar through positive effect.

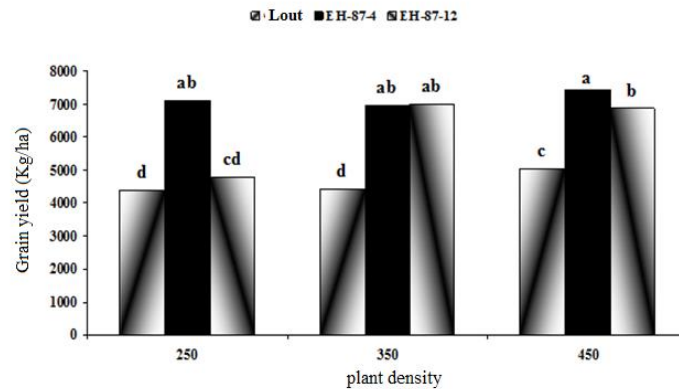


Diagram 3- Mean comparison of interaction of cultivar x density on trait of Grain yield

Harvest index

Results of ANOVA showed that effect of cultivar and plant density on trait of harvest index was significant in probability level of 1% but interaction of these two factors on it was not significant (Table 2). Means comparison showed that Lot cultivar had the lowest harvest index (48.42%) and two other cultivars i.e. EH-87-4 and EH-87-12 (with 52.22 and 50.53%, respectively) were included in top statistical group without significant difference (Table 3). The highest plant density i.e. 450 plants per m² caused the highest harvest index (52.28%) and two other densities lacked significant difference (Table 3). In study by Dashti Nejad et al [15] interaction of the cultivar and plant density on harvest index was not significant. This was in line with results of this test. Increase in plant density due to higher biological yield than grain yield (economic) caused descending trend of harvest index [12]. EH-87-4 cultivar had higher harvest index due to higher grain yield.

Biological yield

According to results of ANOVA, interaction of the cultivar and plant density on this trait was significant in probability level of 5% (Table 2). Mean comparison of the interaction of treatments showed that different treatments were divided into two separate statistical groups in terms of biological yield and treatment of EH-87-4 cultivar in all three plant densities along with EH-87-12 cultivar had the highest biological yield in two high plant densities (Table 3). Lak et al [21] studying different densities on barley cultivars showed that interaction of genotype and density became significant for biological yield. In study by Dashti Nejad et al [13] difference between the cultivars was significant in probability level of 5% in terms of biological yield and the highest biological yield belonged to 10th global cultivar with density of 550 plants in m². Malek Maleki et al. [25] found that increase in plant density led to more desirable distribution of sources such as light, food and humidity among the plants and this reaction led to increased biological yield. Increase of plant density enhanced grain yield of EH-87-12 cultivar. In other words, this cultivar showed positive reaction to higher plant densities. EH-87-4 cultivar was desirable in terms of grain yield and most related agricultural traits in all three plant densities in this test. Lack of low potential of the cultivar or compensatory characteristic through fertile tiller causes different reaction by special cultivar to different plant densities.

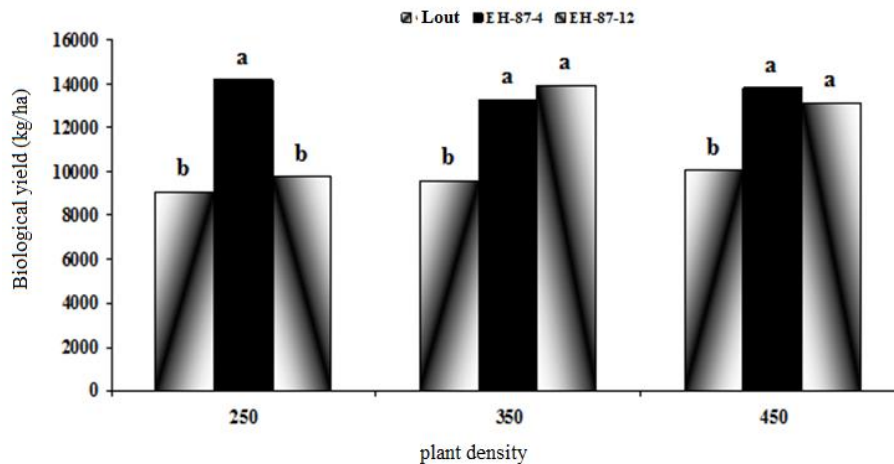


Diagram 4- Mean comparison of interaction of cultivar × density on trait of Biological yield

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