ISSN 2349-0837

Yield and Seed quality of barley (Hordeum vulgare L.) as affected by variety, nitrogen level and harvesting time

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Abstract

The experiment was conducted to find out the effect of variety, nitrogen level and harvesting time on yield and seed quality of barley. The treatments used in the experiment consisted of two varieties *viz.* BARI Barley 4 and BARI Barley 5, three harvesting time *viz.* 35, 40 and 45 Days after Anthesis (DAA) and nitrogen levels *viz.* 0, 70, 85 and 100 kg N ha^{-1}. The experiment was laid out in a spilt- spilt-plot design with three replications assigning the variety to the main plot, harvesting time to the sub-plots and nitrogen level to the sub-sub plots. Variety had significant effects on the all yield attributes except fertile seeds $spike^{-1}$. Seed quality parameters *viz*. normal seeds $spike^{-1}$, deformed seeds $spike^{-1}$, germination (%) and vigour index were statistically significant. The variety BARI Barley 5 produced higher grain yield and seed quality than BARI Barley 4. Grain yield from BARI Barley 5 and BARI Barley 4 were 4.59 t ha^{-1} and 4.24 t ha^{-1}, respectively. Significantly, the highest 1000-seed weight (46.90 g) was produced by BARI Barley 5 than (37.90 g) BARI Barley 4. The result revealed that harvesting time had significant effect on yield and yield attributes and seed quality parameters. Seed yield was highest (4.65 t ha^{-1}) when the crop harvested at 40 DAA and it was increased linearly from 35 DAA. Maximum quality seed and 1000-seed weight (43.20 g) was obtained when the crop harvested at 40 DAA. All the yields, yield attributes and seed quality parameters were significantly influenced by nitrogen levels. The highest grain yield (5.14 t ha^{-1}) was obtained when BARI Barley 5 variety was fertilized by 100 kg N ha^{-1} and the lowest (3.14 t ha^{-1}) was obtained from control treatments. Normal seeds $spike^{-1}$, vigour index, germination (%) were better at 85 kg N ha^{-1} in variety of BARI Barley 5 than BARI Barley 4. So it can be concluded that BARI Barley 5 showed better result when fertilized with 100 kg N ha^{-1} and harvested at 40 DAA for getting maximum yield and 85 kg N ha^{-1} and harvested at 40 DAA for getting better quality seed.

Keywords : Yield; seed quality of barley; variety; nitrogen level; harvesting time

Council for Innovative Research

Peer Review Research Publishing System

.Journal: JOURNAL OF ADVANCES IN AGRICULTURE

Vol 2., No 2

jaaeditor@gmail.com

www.cirjaa.com

ISSN 2349-0837

Introduction

Barley (*Hordeum vulgare* L.) is a fast growing, cool season, annual grain crop, that could be used as forage as well as cover crop to improve soil fertility (Ghanbari *et al.* 2012). It ranks fifth among crops in grain production in the world after maize, wheat, rice and soybean (Miralles *et al*. 2001; Ofosu-Anim and Leitch, 2009; Zeid, 2011; Soleymani and Shahrajabian, 2011). In 2013-14, the total production of barley in the world was 140.10 million metric tons. In 2012-13, the production of barley in Bangladesh was 7000 metric tons (USDA, 2013). Barley (*Hordeum vulgare* L.) is believed to have originated in Abyssinia and south-eastern Asia. It is an important cereal crop in the world cultivated in temperate and subtropical areas. It ranks fourth with respect to area and production among cereals after wheat, rice and maize. It occupies about 9.4% of the total cereal acreage with about 7.8% of the total cereal production in the world. The total barley production in the world is 135.54 million tons in 2010-11 (Agro-stats, 2010).

In Bangladesh barley is a minor crop but it has the potential to become one of the important crops in Bangladesh and can play an important role in enhancing the food security of the country and in drainage of foreign currency. The crop covers an area of about 2000 acres and produces about 1000 metric tons in this country (BBS, 2008) with a very low average yield of 1.5 mt. ha^{-1} as compared to other barley growing countries having a yield gap of 2.51 mt. ha^{-1} (FAO, 1993-2002). In 2010-11 production of barley in Bangladesh was 7000 metric tons (USDA, 2011).

The most important use of barley throughout the world is as malt for manufacturing beverages or malt enriched food products. In Bangladesh, it is widely used as chatu (barley flour mixed in sugar and water). Chapati can also be made by mixing barley and wheat flour. Diluted soup made from barley is used to feed the infants as horlicks, ovaltine, Robinson's barley, Alberta barley, Hamilton's barley flour pancake mix, multova etc. These are the baby foods, for which in Bangladesh, several industries and pharmaceutical companies have to import a large amount of barley grain and malt extract for manufacturing patented baby food and medicine. Barley grain contains starch (61.8%), protein (13.1 %), insoluble fibre (10.8%), moisture (7.55%), soluble fibre (4.85%), pentosan (4.28%), β-D glucan (4.26%), lipid (2.92%) and ash (1.89%) (Helam *et al.*1999). Foods prepared from barley are useful for diabetic and high blood pressure patients. It is suggested that barley could be therapeutic diet for diabetic patients, a good diet for kidney patients and the referred diet after convalescence (Ikegami *et al*. 1991). Barley contains water soluble fibre named beta-glucans and an oil compound named to coronel which are found to be very effective in lowering blood cholesterol level (Hales, 1992). Barley grain is also used in poultry industries. So, huge amounts of barley were imported every year in Bangladesh from different countries.

The yield of barley in the farmer's field is much lower than that in the research farm (Anonymous, 1990). The yield and quality of barley seed is known to be influenced by several factors such as variety, time of sowing, seed rate, fertilizer doses, water and nutrient management, harvesting time and other agronomic practices.

Variety has also played an important role in producing better yield and seed quality of barley. Different varieties respond differently for their genotypic characters, input requirement, growth process and the prevailing environment during growing season. Now Bangladesh has a number of modern varieties of barley *viz.* BARI Barley 1, BARI Barley 2, BARI Barley 3, BARI Barley 4, BARI Barley 5, BARI Barley 6 etc. Yield and yield contributing attributes like plant height, number of tillers, number of spikelets, spike length, grain size, grain yield and other yield attributes and quality of seeds differ from one variety to another.

Among the nutrient elements, nitrogen plays a vital role in growth and development of the crop and also affects the seed quality at its optimum level. Although judicious dose of nitrogen elevates the yield and quality of seed but the excessive dose cause the economic loss as well as reduced yield and quality of barley seeds. The optimum dose of nitrogen varies from location to location.

The yield attributes and quality of barley seed is therefore, dependent on the harvesting time as well as appropriate dose of applied nitrogen. The time of proper stages of harvesting and optimum dose of nitrogen depends on the climate and soil of the location as well as the variety used. Therefore, the present investigation was undertaken to study the effect of nitrogen rate and harvesting time on yield and yield attributes and seed quality of barley varieties and to investigate the interaction effect among varieties, harvesting time and nitrogen on yield, yield attributes and seed quality of barley.

Methods

The present research work was carried out at Agronomy field laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi during the rabi season from November 2011 to April 2012 to study the effect of variety, harvesting time and nitrogen level on the yield and seed quality of barley. The experimental farm is located at the western side of Agronomy & Agricultural Extension Department. Geographically the experimental field was located at 24°22′36″ N latitude and 88°38′27″ E longitude at an elevation of 71ft. above the sea level belonging to the Agro-ecological Zone-11 (AEZ- 11).The experimental field was a medium high land with sandy loam textured soil having p^H value of 7.56. The experimental area was situated under subtropical climate characterized by heavy rainfall during kharif season (April to September) and scanty rainfall during rabi season (October to March).The experiment consisted of the following three factors:

Factor A. Number of variety: 2

i. V_1 = BARI Barley 4
ii. V_2 = BARI Barley 5

Factor B. Number of harvesting time: 3

i. H_1 = 35 days after anthesis
ii. H_2 = 40 days after anthesis
iii. H_3 = 45 days after anthesis

Factor C. Number of nitrogen Level: 4

	N-level	kg ha^{-1}
i.	N_0 =	control

ISSN 2349-0837

ii. N_1 = 70

iii. N_2 = 85

iv. N_3 = 100

The experiment was laid out in a split-split plot design assigning the variety on the main plot, harvesting time to the sub-plots and nitrogen level to the sub-sub plots. The treatments were replicated three times. Each block was divided into three main plots in which variety were applied at random. Each main plot was further divided into three sub- plots and harvesting time was allocated to these plots at serially. Then each sub plot was again divided into three sub-sub plots and nitrogen levels were assigned in these plots at random. So, the total numbers of unit plots in the entire experimental area were 2×3×4×3= 72. The plot size was 2m×2m. The plot to plot distance was 0.50 m and the block to block distance was 1.0 m.Two barley varieties i.e. BARI Barley 4 and BARI Barley 5 were used as planting materials. BARI Barley 4 and BARI Barley 5 were developed by Bangladesh Agricultural Research Institute (BARI). The land of the experimental plot was opened on 3 November 2012 with a power tiller and it was made ready for sowing on 13 November by ploughing and cross ploughing with a country plough followed by laddering. All weeds and stubbles were removed from the land. The experimental field was fertilized with above mentioned four nitrogen levels *viz.* 0, 70, 85, 100 kg N ha^{-1}. Urea in one-third was applied at the time of final land preparation, one-third at 25 DAS and rest of one-third at 55 DAS. All other fertilizers *viz*. TSP, MOP and Gypsum at the rate of 125, 100 and 100 kg ha^{-1}, respectively were applied at the final land preparation. Seeds of designated barley varieties were collected from BARI, Gazipur. The initial germination percentage of the seeds was 85% for each variety. Before sowing collected seeds were treated with Vitavax-200 WP @ 4 g kg^{-1} seed to prevent seeds from the attack of soil borne diseases. Seeds were sown on 13 November 2012 in 25 cm apart rows opened by specially made hand rake. Seeds were placed 4 cm depths. After sowing the seeds were covered with soil and slightly pressed by hands. Care was taken to protect the seedlings from birds. The crop was infested with some local weeds such as Durba (*Cynodon dactylon*), Bathua (*Chenopodium album*), Mutha (*Cyperus rotundus*) which were controlled by hand hoe. Two weeding at 25 and 55 DAS were done to control weeds in the experimental field. Two irrigations were applied. First irrigation was applied at 25 DAS and second irrigation at 55 DAS followed by weeding. Leaf blight disease was found in the experimental field. It was not observed in the Economic threshold level (ETL). This disease was controlled by spraying Tilt 250 EC @ 2 ml/L. Malathion was applied to control aphid. The crop started flowering more or less at the same time in different plants. All the varieties matured at the same time and harvesting were done on 35 days after anthesis (1st harvesting), 40 days after anthesis (2nd harvesting) and 45 days after anthesis (3rd harvesting). The harvested crop was bundled separately, tagged properly and taken to the clean threshing floor and sun dried for three days. Then threshing, cleaning, winnowing and drying of grains were done properly. The seeds were dried in the sun for consecutive three days till to reach to a constant weight. After that the seeds were stored carefully in polythene bags of 0.04 mm thickness. The germination test was carried out on 15 April 2011 of the harvested seeds. The plant height was taken from five randomly selected plants of each plot. The height of the plant was measured from the base of the plant to the tip of the upper most spikelets $spike^{-1}$. Tillers $plant^{-1}$ that had at least one leaf visible was counted. It included both effective and non-effective tillers. The spike, which had seeded, was regarded as effective tillers. Spike length (cm) was taken from basal node of the rachis to the apex of last grains of each spike. Spikelets $spike^{-1}$ was recorded and mean was calculated later on. Presence of any food material in the spikelet was considered as filled seeds present on each spike were counted. Presence of any food material in the spikelet was considered as grain and total number of grains present on each spike was counted. One thousand grains were counted from grains of the sample plants of each treatment plot, dried properly and weight by using an electric balance. Grain yields were determined by harvesting crops grown one square meter area at the center of each plot. The harvested samples were then threshed, dried, weighted and the values were expressed in t ha^{-1}. Straw yields obtained from each unit plot including the straw of sample plants of respective unit plot were dried in sun and weight to record the final straw yield $plot^{-1}$ and the values were converted to t ha^{-1}.

Statistical analysis

The recorded data were compiled and tabulated for statistical analysis. The data were analyzed statistically using the statistical package "MSTATC" and the mean differences among the treatments were adjudged by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Results and discussion

Variety had significant effects on the all yield and yield attributes except fertile seeds $spike^{-1}$. Seed quality parameters *viz*. normal seeds $spike^{-1}$ deformed seeds $spike^{-1}$, germination (%) and vigour index were statistically significant. The highest total tillers $plant^{-1}$, effective tillers $plant^{-1}$, spike length, spikelets $spike^{-1}$, fertile spikelets $spike^{-1}$, fertile seeds $spike^{-1}$, 1000-seed weight, seed yield, straw yield and biological yield were obtained from BARI Barley 5. The highest germination percentage (89.19 %) and vigour index (36.40) were produced by BARI Barley 5 and the lowest germination percentage (84.00%) and vigour index (29.58) were obtained from BARI Barley 4.

Harvesting time had significant effects on all yield and yield attributes and seed quality. The highest seed yield (4.65 t ha^{-1}) was obtained when crop was harvested at 40 DAA and the lowest (4.25 t ha^{-1}) result was obtained when harvested at 35 DAA. The highest normal seeds $spike^{-1}$ was produced when harvested at 40 DAA. On the other hand, the lowest normal seeds $spike^{-1}$ (49.72) was produced in the time of harvesting at 35 DAA. The result of the present investigation revealed that the seed yield increased with delay in harvest up to 40 DAA irrespective to the variety and there after the yield was found reduced (Park *et al.* 1989). The highest germination percentage (88.55%) was produced in harvesting at 40 DAA and the lowest germination percentage (85.10%) was obtained when the crop harvested at 35 DAA. Park *et al.* (1989) reported that germination increased with the delayed harvesting as grain moisture content decreased. Vigour index was also higher (34.12) when harvested at 40 DAA. Similar result was obtained by Dell and Tritto (1991).

Kumar (2005) reported that the number of total tillers $plant^{-1}$ was significantly increased with increasing nitrogen rate. Nitrogen level had significant effect on all the yield and yield attributes and seed quality. The highest effective tillers $plant^{-1}$

(7.24), spikelets spike^{-1} (20.96), fertile spikelets spike^{-1} (20.59), fertile seed spike^{-1} (52.10), 1000-seed weight (45.04 g), seed yield (5.14 t ha^{-1}), straw yield (9.01 t ha^{-1}) were obtained from the level 100 kg ha^{-1} N i.e. N_3 Level. Singh *and Singh* (1993) reported that number of effective tillers plant^{-1} increased with increasing rates of nitrogen. Hossain (2005) reported that grain spike^{-1} increased significantly with each increase in N rate. Result revealed for seed yield, 1000- seed weight that was supported by Ayoub *et al.* (1991) and BARI (2005) respectively.

The quantity of normal seeds spike^{-1} (54.39) was highest at the level of 85 kg N ha^{-1} and the lowest normal seeds spike^{-1} was produced in level of control condition. The highest germination percentage (92.39%), the result is consistent with that of Bengtsson (1992) and Thimmaiah *et al.* (1988) and vigour index (37.54), similar findings were also obtained by Thimmaiah *et al.* (1988). were obtained from the level of 85 kg N ha^{-1} and the lowest germination percentage (81.05 %) and vigour index (29.27) were obtained from control condition.

Interaction effect of variety and harvesting was not significantly for spike length, fertile seeds spike^{-1}, straw yield and biological yield. The quality of seed *viz*. deformed seeds spike$^{-1;}$ germination (%) and vigour index were recorded statistically significant except normal seeds spike^{-1}. Similarly, the highest effective tillers plant^{-1} (7.13) was produced with the combination between $V_2 \times H_2$. The highest grain yield (4.94 t ha^{-1}) was obtained with the combination of variety BARI Barley 5 when harvested at 40 DAA. On the other hand, the highest germination percentage (91.19 %) and vigour index (37.50) were produced by the combination of variety BARI Barley 5 when harvested at 40 DAA ($V_2 \times H_2$).

Variety and nitrogen level interacted non-significantly for plant height, total tillers plant^{-1}, effective tillers plant^{-1}, spike length, fertile seeds spike^{-1}, grain yield, straw yield, biological yield, harvest index, normal seed spike^{-1} except spkelets spike^{-1}, fertile spkelets spike$^{-1,}$ 1000-seed weight, deformed seeds spike^{-1}, germination (%) and vigour index. The highest spikelets spike^{-1} (22.60) was obtained from the variety BARI Barley 5 which fertilized with 100 kg N ha^{-1}. The maximum germination (94.83%) and vigour index (39.70) were obtained from the combination of variety BARI Barley 5 with 85 kg N ha^{-1} ($V_2 \times N_2$).

The interaction effect between harvesting time and nitrogen level was not found to be significant for plant height, fertile spikelets spike^{-1}, fertile seeds spike^{-1}, 1000-seed weight, harvest index and normal seeds spike^{-1} except total tillers plant^{-1}, effective tillers plant^{-1}, spike length, grain yield, straw yield, biological yield, deformed seeds spike^{-1}, germination (%) and vigour index. The highest spike length (20.89 cm) was obtained from the combination of 100 kg N ha^{-1} and the crop harvested at 40 DAA. The highest germination (94.46%) and vigour index (39.15) were obtained from N_2 (85 kg ha^{-1}) and harvested at 40 DAA (Table 1-2).

Simple correlation co-efficient between yield and yield attributes of barley

The correlation matrix of the selected parameters is presented in Table 3. The relationship between grain yield and effective tillers plant^{-1}, grain yield and fertile spikelets spike^{-1}, grain yield and fertile grains spike^{-1}, grain yield and 1000-grain weight have been presented in graphical form. The degree of relationship between effective tillers plant^{-1} and grain yield of barley was studied . The result revealed that effective tiller plant^{-1} and grain yield have a significant positive relationship at 1% level of significance. The correlation co-efficient r= 0.945**. The positive slope indicates positive relationship which means that an increase in the number of effective tiller plant^{-1} will lead to an increase in grain yield of barley. The degree of relationship between spikelets spike^{-1} and grain yield of barley was studied. The result revealed that spikelets spike^{-1} and grain yield have a significant positive relationship at 1% level of significance. The correlation co-efficient r= 0.729**. The positive slope indicates positive relationship which means that an increase in the number of spikelets spike^{-1} will lead to an increase in grain yield of barley. The degree of relationship between fertile grains spike^{-1} and grain yield of barley was studied . The result revealed that fertile grains spike^{-1} and grain yield have a significant positive relationship at 1% level of significance. The correlation co-efficient r= 0.791**. The positive slope indicates positive relationship which means that an increase in the number of fertile grains spike^{-1} will lead to an increase in grain yield of barley. The degree of relationship between 1000-Seed weight and grain yield of barley was studied. The result revealed that 1000-Seed weight and grain yield have a significant positive relationship at 1% level of significance. The correlation co-efficient r= 0.599**. The positive slope indicates positive relationship which means that an increase in the number of 1000-Seed weight will lead to an increase in grain yield of barley (Table 3).

Conclusion

The overall result demonstrated that BARI Barley 5 was better than BARI Barley 4 for yield, yield attributes and seed quality. So it can be concluded that BARI Barley 5 can be cultivated with 100 kg N ha^{-1} and harvested at 40 DAA for getting maximum yield and 85 kg N ha^{-1} and harvested at 40 DAA for getting better seed quality.

Acknowledgments:

Authors have no conflict of interest in this research. The generous funding from Department of Agronomy and Agricultural Extensione, University of Rajshahi, Bangladesh, supported this work.

ISSN 2349-0837

Table 1. Analysis of variance for the yield and yield attributes of Barley as influenced by variety, harvesting time and nitrogen level

Sources of variation (SV)	Degrees of freedom	Means square values											
		Plant height (cm)	Total tillers plant^{-1} (no.)	Effective tillers plant^{-1} (no.)	Spike length (cm)	Spikelets spike^{-1} (no.)	Fertile spikelets spike^{-1} (no.)	Fertile seeds spike^{-1} (no.)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	25.34	0.08	0.05	0.62	2.71	2.64	0.07	3.69	0.11	0.04	0.07	3.77
Factor A	1	259.54*	5.55*	3.70*	11.8*	68.95*	62.24*	74.71	1459.4**	2.22**	1.20*	6.69**	19.26*
Error	2	5.95	0.16	0.29	0.21	3.27	2.05	5.09	1.05	0.02	0.02	0.06	1.02
Factor B	2	272.3**	8.26**	7.86**	8.03**	15.27**	12.40**	37.54**	14.26**	1.07**	4.89**	9.54**	19.70**
AB	2	29.27*	0.34**	0.74**	0.40	6.73**	4.38**	0.55	3.30*	0.23**	0.09	0.33	6.99*
Error	8	4.66	0.02	0.08	0.48	0.27	0.36	2.88	0.47	0.02	0.07	0.10	1.33
Factor C	3	4690.8**	42.2**	39.50**	28.7**	28.34**	27.48**	125.5**	120.9**	14.7**	67.8**	145.45**	55.56**
AC	3	3.14	0.09	0.09	0.32	4.43**	3.37**	0.84	3.9*	0.08	0.03	0.20	0.80
BC	6	9.08	0.44**	0.61**	0.55**	0.57**	0.31	4.10	0.75	0.12**	0.30**	0.62**	3.03
ABC	6	4.00	0.15*	0.09	1.22*	0.68	0.63	1.13	0.88	0.10*	0.06	0.26*	1.53
Error	36	18.12	0.05	0.11	0.47	0.55	0.45	2.78	1.19	0.03	0.05	0.09	1.79
CV (%)		3.64	3.37	5.41	3.75	3.80	3.47	3.39	2.57	4.20	3.03	2.48	3.59

Key: *= Significant at 5% level of probability, **= Significant at 1% level of probability, CV= Co-efficient of variation, NS=Not Significant

ISSN 2349-0837

Table 2. Analysis of variance for normal seed, deformed seed, germination (%) and vigour index of Barley as influenced by variety, harvesting time and nitrogen level

Sources of variation (SV)	Degrees of freedom	Means square values			
		Normal seeds spike^{-1} (no.)	Deformed seeds spike^{-1} (no.)	Germination (%)	Vigor index
Replication	2	2.72	0.01	1.38	2.90
Factor A	1	105.92**	2.53**	485.63*	838.99**
Error	2	0.26	0.01	7.92	4.20
Factor B	2	66.06*	2.62**	74.74*	27.09**
AB	2	13.33	0.32**	0.60**	2.47*
Error	8	8.40	0.01	3.73	4.79
Factor C	3	700.79**	6.32**	408.84**	215.0**
AC	3	0.91	0.13**	5.73**	18.66**
BC	6	5.74	0.10**	2.09**	6.33**
ABC	6	7.74	0.20**	1.69**	8.22*
Error	36	65.45	0.01	3.53	3.21
CV (%)		2.65	3.96	2.17	5.43

Key: *=Significant at 5% level of probability, **= Significant at 1% level of probability, NS=Not Significant,

CV= Co-efficient of variation

ISSN 2349-0837

Table 3. Simple correlation co-efficient between yield and yield components of barley as influenced by variety, harvesting time and nitrogen level

	Plant Height (cm)	Total Tiller Plant^{-1} (no.)	Effective Tiller Plant^{-1} (no.)	Spike length (cm)	Spikelets spike^{-1} (no.)	Fertile Spikelets spike^{-1} (no.)	Fertile seeds spike^{-1} (no.)	1000 Grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index
Plant height (cm)	-	0.931**	0.921**	0.778**	0.665**	0.688**	0.778**	0.531**	0.937**	0.956**	0.962**	-0.592**
Total tiller plant^{-1} (no.)		-	0.988**	0.848**	0.746**	0.763**	0.838**	0.600**	0.950**	0.945**	0.959**	-0.516**
Effective tiller plant^{-1} (no.)			-	0.823**	0.730**	0.743**	0.819**	0.568**	0.945**	0.938**	0.953**	-0.511**
Spike length (cm)				-	0.815**	0.800**	0.855**	0.636**	0.820**	0.770**	0.797**	-0.290*
Spikelet's spike^{-1} (no.)					-	0.986**	0.790**	0.803**	0.729**	0.648**	0.684**	-0.171
Fertile Spikelet's spike^{-1} (no.)						-	0.772**	0.810**	0.747**	0.672**	0.706**	-0.211
Fertile seeds spike^{-1}(no.)							-	0.665**	0.791**	0.769**	0.786**	-0.331**
1000-grain weight (g)								-	0.599**	0.493**	0.535**	-0.054
Grain yield (t ha^{-1})									-	0.941**	0.973**	-0.416*
Straw yield (t ha^{-1})										-	0.994**	-0.691**
Biological yield (t ha^{-1})											-	-0.609**
Harvest index												-

Key: ** Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level (2-tailed).

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Current International Publication:

Growth and yield of barley *(Hordeum vulgare* L.) as affected by irrigation, sowing method and phosphorus level. Acad. J. Agric.Res. 2(1): 030-035.(2014)