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Effect of seed soaking with fertigrain start (amino acid fertilizer) and irrigation levels on germination, growth and yield of barley (*Hordeum vulgare* L.)

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Abstract

The field study was conducted to investigate the effect of seed soaking with Fertigrain start (amino acid fertilizer) and moisture stress on germination, growth and yield of barley crop. The results showed that application of Fertigrain Start (amino acid fertilizer) for soaking of seed at different concentrations affected the growth and yield traits of barley significantly ($P<0.05$); while the water stress also significantly ($P<0.05$) affected all the growth and yield traits with the exception of grains spike^{-1}. The seed of barley crop was soaked with Fertigrain Start @3mlkg^{-1} seed resulted in highest values for all the traits investigated with 164.33m^{-2} seed germination, 469.11 tillers m^{-2}, 87.66cm plant height, 16.256 cm spike length, 8002.40kg biological yield ha^{-1}, 33.767 grains spike^{-1}, 47.60g seed index, 2730.00kg grain yield ha^{-1} and 34.03% harvest index. The seed of barley when soaked with lower concentration of Fertigrain Start (1.5ml kg^{-1} seed) ranked 2nd and ranked least when seed was sown without soaking with Fertigrain Start. Similarly, the barley crop receiving two irrigations after 30 and 60 days of sowing produced 140.22 m^{-2} seed germination, 422.67 tillers m^{-2}, 95.55 cm plant height, 13.70cm spike length, 7945.60kg biological yield ha^{-1}, 39.867 grains spike^{-1}, 54.133g seed index, 2747.70kg grain yield ha^{-1} and 34.49% harvest index. The crop given only one irrigation after 30 days of sowing and no post-sowing irrigation (only soaking dose) ranked 2nd and 3rd, respectively for all the growth and yield traits.

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Introduction

Barley (*Hordeum vulgare* L.) is a most important cereal crop that is also a source of making bread and there are varieties of uses in making beverages for human consumption. Besides this, barley is also used in manufacturing of soups, stews and the barley flour contains gluten like rye and wheat flours. The barley can be cultivated even under severe water stress and hardy in nature withstand under harsh climates (Mishra and Shivakumar, 2000). In Pakistan, the area under barley crop during 2011-12 was 72 thousand hectares with a production of 66 thousand tons; while the area slightly decrease to 71 thousand hectare during the year 2012-13 with production of 62 thousand tons showing a decrease of 6.2 percent over the preceding year 2011-12 (GoP, 2013). The crop stand establishment coupled with management options and uniformity (Cheng and Bradford, 1999) describes the density of the plants.

Seed priming is one of the effective methods for increasing the rate of germination, seed germination uniformity and seed physical advancement (Halmer, 2004). For seed priming, the crop seed is soaked in any of the suitable solution of the seed-soaking agent (McDonald, 1999). The seed priming is processed by many techniques; of these soaking seed in water is common, while soaking of seed in inorganic solutions based on salts, using various organic osmotic for soaking seed, treating the seed to be sown with different temperatures, seed treatment by solid matrices and seed treatment by biological compounds (Ashraf and Foolad, 2005; Khan, 1992; Ghassemi *et al*., 2008; Mc Donald, 2000). The seed priming process also improves anti-oxidative enzyme and glyoxysome enzyme activities is in the soaked seeds (Lin and Sung, 2001; Hsu *et al*., 2003).

Similarly, irrigation water is one of the most important factors that regulate plant nitrogen metabolism; and its shortage affect grain yield by reducing tillers, ear heads and grain number (Musick and Dusek, 1980). Irrigation frequencies also influences crop yield (Kumar *et al.,* 1983). Cereals appeared to be most sensitive to water stress during tillering, heading and milk-ripe stages (Ahmed and Badar, 2004).

Irrigation stress during reproductive stage resulted reduction in seed yield (Dhaka *et al.,* 2007) reduced crop growth traits including crop growth rate, leaf area index and net assimilation rate (Jazy *et al.,* 2007). There were remarkable impacts of seed soaking on all the traits measured in barley (Ibrahim *et al.,* 2011). Apart from the good seedbed and other soil nutrients requirements, seed soaking or seed priming has proved to be an effective practice for rapid seed emergence and improved crop stand. Keeping in view the importance of seed soaking and irrigations, the present study was proposed to investigate the effect of seed soaking with Fertigrain Start (Amino Acid Fertilizer) and moisture stress on germination, seedling growth and physical productivity of barley under agro-climatic conditions of Tandojam, Sindh-Pakistan.

Materials and methods

The field experiment was conducted in a three replicated split plot design with factorial arrangements during 2013-2014 at the Students' Farm, Department of Agronomy, Sindh Agriculture University Tandojam having plot size of 5m x 3m ($15m^2$). The seedbed was prepared for sowing of barley according to the recommended package of production technology. The seed of local barley variety was soaked with Fertigrain at different concentrations; and experimental barley was treated with different levels of irrigations. The sowing was done with single coulter hand drill.

Treatments Used

Main Plot: Irrigation levels (I) = 3

I_1 = Soaking dose (Control)

I_2 = One irrigation (30 DAS)

I_3 = Two irrigations (30 and 60 DAS)

Sub-Plot: Fertigrain Start levels (F) = 3

F_1 = No seed soaking with Fertigrain Start (Control)

F_2 = Seed soaking with Fertigrain Start @ 1.5ml kg^{-1} seed

F_3 = Seed soaking with Fertigrain Start @ 3.0ml kg^{-1} seed

The NPK fertilizers were applied at the recommended dose i.e. 168-84-50kg ha^{-1}. N was applied in the form of urea, while P in the form of single superphosphate; whereas the K was applied in the form of sulphate of potash.

The crop was irrigated as per the general recommendation, and other cultural operations in all the plots were performed uniformly. The details of cultural operations are as under:

Land preparation

The land was prepared by giving two dry plowings, followed by land leveling. After soaking dose when land came in condition, it was plowed crosswise with cultivator, followed by rotavator and planking for achieving a good seedbed.

Sowing time and method

The seed of barley variety "Local" at recommended rate of 100kg ha^{-1} was sown with single row hand drill in the 1st week of November 2012 maintaining row to row distance of 22.5cm.

Weeding

All narrow leaf and broad leaf weeds were controlled by applying suitable post-emergence herbicides recommended for barley crop.

Crop harvesting and threshing

At maturity five plants from each treatment of all replications was selected at random for harvest. These plants were harvested by cutting at soil level with sickle. The spikes were separated from straw, placed in separate paper bags, oven-dried for 24 hours at 78°C and threshing was carried out manually.

The observations were recorded on the following parameters: Following Observations were recorded during our study:

1. Seed germination (m^{-2})
2. Tillers (m^{-2})
3. Plant height (cm)
4. Spike length (cm)
5. Biological yield (kg ha^{-1})
6. Grains $spike^{-1}$
7. Seed index (g)
8. Grain yield (kg ha^{-1})
9. Harvest index (%)

Statistical analysis

The data collected were subjected to statistical analysis using Statistix 8.1 (Statistix, 2006). The LSD test was applied to compare treatments superiority, where necessary.

Layout Plan of The Experiment

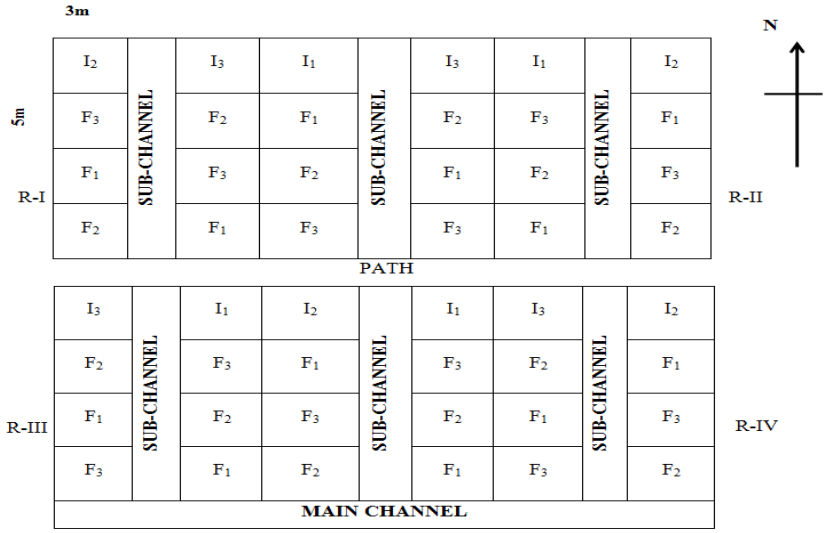
Experimental design = Split Plot Design (SPD)
Replications = Four
Variety = Local
Net plot size = 5m x 3m ($15m^2$)

Main Plot: Irrigation levels (I) = 3

I_1 = Soaking dose (Control)
I_2 = One irrigation (30 DAS)
I_3 = Two irrigations (30 and 60 DAS)

Sub-Plot: Fertigrain Start levels (F) = 3

F_1 = No seed soaking with Fertigrain Start (Control)
F_2 = Seed soaking with Fertigrain Start @ 1.5ml kg^{-1} seed
F_3 = Seed soaking with Fertigrain Start @ 3.0ml kg^{-1} seed



Results

The field experiment was conducted to investigate the effect of seed soaking with fertigrain start (amino acid fertilizer) and moisture stress on germination, growth and yield of barley. The experimental crop was examined for seed germination (m^{-2}), tillers (m^{-2}), plant height (cm), spike length (cm), biological yield (kg ha^{-1}), grains $spike^{-1}$, seed index (g), grain yield (kg ha^{-1}) and harvest index (%). The results on above mentioned traits are defined one by one.

Seed germination (m^{-2})

The seed viability and germination is the primary factor for achieving a good crop stand, and seed priming with different seed pirming agents has significant role in quicker seed germination and healthy seedling emergence. The effect of amino acid fertilizer (Fertigrain start) on seed germination of barley was examined. The results further described significant impact ($P<0.05$) of seed soaking with Fertigrain Start at varying concentrations, while non-significant ($P>0.05$) for irrigation levels as well as their interactions.

The germination of barley seed was highest (164.33m^{-2}) when the seed was soaked with Fertigrain Start @ 3.0ml kg^{-1} seed; and decrease in Fertigrain Start level up to 1.5ml kg^{-1} seed showed a marked reduction in seed germination (142.44m^{-2}); while the lowest seed germination (114.89m^{-2}) was observed in control, where the seed was not soaked with Fertigrain Start. In case of water stress effects on seed germination, the crop receiving one irrigation after 30 days of sowing showed slightly higher germination (141.44m^{-2}) than the soil irrigated twice and soaking dose only with average seed germination of 140.22 and 140m^{-2}, respectively. The treatment interaction showed that Fertigrain Start @ 3.0ml kg^{-1} seed × 2 irrigations resulted in highest seed germination of 165.67m^{-2} and the interaction of No Fertigrain Start for seed priming × soaking dose only resulted in lowest seed germination of 114.33m^{-2}.

It was observed that seed priming with amino acid fertilizer 'Fertigrain Start' proved to be effective to enhance seed germination in barley and statistically, the Fertigrain Start @ 3.0ml kg^{-1} seed was an optimum concentration for seed priming (Table 1).

Table 1. Seed germination (m^{-2}) of barley as affected by Fertigrain Start and irrigation levels.

Fertigrain Start levels	Irrigation levels			Mean
	Soaking dose (control)	One irrigation (30 DAS)	Two irrigations (30 & 60 DAS)	
No seed soaking with Fertigrain Start (Control)	114.3	115.3	115.0	114.9 C
Seed soaking with Fertigrain Start @ 1.5 ml kg^{-1} seed	142.3	145.0	140.0	142.4 B
Seed soaking with Fertigrain Start @ 3.0 ml kg^{-1} seed	163.3	164.0	165.6	164.3 A
Mean	140.0	141.4	140.2	-----

	Fertigrain levels (F)	Irrigation levels (I)	F x I
SE±	2.1038	2.1038	3.6439
LSD 0.05	4.4598	-	-
LSD 0.01	6.1447	-	-

Tillers (m^{-2})

Tillering capacity although is generally infleunced by genetic makeup of varieties, but the influence of applied inputs is also well recognized. Moreover, healthy seedling emergenged also impact positively to this parameter. The analysis of variance suggested significant effect ($P<0.05$) of seed soaking with Fertigrain Start at varying concentrations, and irrigation levels, but their interactive effect was non-significant ($P>0.05$). The tillers $plant^{-1}$ in barley were highest (469.11m^{-2}) when the seed was soaked with Fertigrain Start @ 3.0ml kg^{-1} seed; followed by Fertigrain Start level of 1.5ml kg^{-1} that resulted 437.78 tillers m^{-2}; while the lowest number of tillers (313.22m^{-2}) was noted in control plots where seed was sown without soaking. In case of water stress effects

on the number of tillers, the crop irrigated twice at 30 and 60 days after sowing produced more tillers (422.67m^{-2}) as compared to the crop irrigated once (405.77m^{-2}) and minimum tillers (391.66m^{-2}) were recorded in plots given soaking dose only.

The treatment interaction showed that Fertigrain Start @ 3.0ml kg^{-1} seed × 2 irrigations resulted in more tillers plant of 481.67m^{-2} and the interaction of No Fertigrain Start for seed priming × soaking dose only resulted in lowest tillers of 286.67m^{-2}. It was observed that seed priming with amino acid fertilizer 'Fertigrain Start' proved to be effective to enhance tillers m^{-2} in barley and statistically, the Fertigrain Start @ 3.0ml kg^{-1} seed with at least 2 irrigations are suggested for achieving higher tillering (Table 2).

Table 2. Tillers (m^{-2}) of barley as affected by Fertigrain Start and irrigation levels.

Fertigrain Start levels	Irrigation levels			Mean
	Soaking dose (control)	One irrigation (30 DAS)	Two irrigation (30 and 60 DAS)	
No seed soaking with Fertigrain Start (Control)	286.6	313.3	339.6	313.2A
Seed soaking with Fertigrain Start @ 1.5 ml kg^{-1} seed	433.3	433.3	446.6	437.7 AB
Seed soaking with Fertigrain Start @ 3.0 ml kg^{-1} seed	455.0	470.6	481.6	469.1B
Mean	391.6 C	405.7 B	422.6 A	-------

	Fertigrain levels (F)	Irrigation levels (I)	F x I
SE±	8.1947	8.1947	14.194
LSD 0.05	17.372	16.723	-
LSD 0.01	8.1947	8.1947	-

Plant height (cm)

The growth traits in cereals including barley are mainly associated with the plant height. Generally, tall varieties produce lower yields as compared to dwarf varieties. The plant height of barley as influenced by effect of amino acid fertilizer (Fertigrain start). There was a significant effect of seed soaking with Fertigrain Start at varying concentrations, irrigation levels as well as their interaction ($P<0.05$). Greater plant height (87.66 cm) was recorded when the seed was soaked with Fertigrain Start @ 3.0ml kg^{-1} seed; while seed soaking with Fertigrain Start at 1.5ml kg^{-1} seed resulted in plant height of 85.11cm; and the minimum plant height (81.55cm) was observed in control plots where seed was sown without soaking. In case of water stress effects on barley growth, the crop two irrigations after 30 and 60 days of sowing produced plants of maximum height (95.55cm) as compared to the crop irrigated once (85.44cm) and minimum plant height (76.33cm) was recorded in plots given soaking dose only. The treatment interaction of Fertigrain Start @ 3.0ml kg^{-1} seed × 2 irrigations interaction resulted in tallest plants on average (95.33cm) and the interaction of No seed soaking × Control irrigation (soaking dose only) resulted in plants minimum height (71.67cm). It was clear from the results that seed priming with amino acid fertilizer 'Fertigrain Start' showed positive impact on plant growth in barley and linear trend of effectiveness was observed for seed soaking and irrigation levels. Hence, seed soaking with Fertigrain Start @ 3.0ml kg^{-1} seed with at least 2 irrigations will produce desired results for plant height (Table 3).

Table 3. Plant height (cm) of barley as affected by Fertigrain Start and irrigation levels.

Fertigrain Start levels	Irrigation levels			Mean
	Soaking dose (control)	One irrigation (30 DAS)	Two irrigation (30 and 60 DAS)	
No seed soaking with Fertigrain Start (Control)	71.6	83.3	89.6	81.5 C
Seed soaking with Fertigrain	77.3	85.3		85.1B

Fertigrain Start levels	Irrigation levels			Mean
	Soaking dose (control)	One irrigation (30 DAS)	Two irrigation (30 and 60 DAS)	
Start @ 1.5 ml kg^{-1} seed			92.6	
Seed soaking with Fertigrain Start @ 3.0 ml kg^{-1} seed	80.0	87.6	95.3	87.6 A
Mean	76.3 C	85.4 B	95.55 A	--

	Fertigrain levels (F)	Irrigation levels (I)	F x I
SE±	0.7731	0.7731	1.3391
LSD 0.05	1.6390	1.3482	2.8388
LSD 0.01	2.2582	2.2582	2.8388

Spike length (cm)

The spike length of barley as affected by varied concentrations of amino acid fertilizer (Fertigrain start) as seed soaking agent and level of water stress. The analysis of variance illustrated that there was a significant impact of seed soaking with Fertigrain Start on spike length ($P<0.05$); while the impact of irrigation levels and treatment interaction on spike length was insignificant ($P>0.05$).

Relatively longer spikes (16.256cm) were observed when the seed was soaked with Fertigrain Start @3.0ml kg^{-1} seed; while reducing Fertigrain Start at concentration to 1.5ml kg^{-1} seed resulted in decreased spike length (12.656 cm); and the minimum spike length (11.044cm) was noted in plots where seed was sown without soaking (Control). In case of water stress impacts, the crop given two irrigations after 30 and 60 days of sowing and one irrigation after 30 days of sowing produced equally longer spikes of 13.70cm and minimum spike length (12.656cm) was recorded in plots given soaking dose only (Control). The treatment interaction of Fertigrain Start @3.0mlkg^{-1} seed × 2 irrigations interaction resulted in longest spikes on average (17.533cm) and the interaction of No seed soaking × Control irrigation (soaking dose only) resulted in minimum spike length (10.567cm). The results further propose that 'Fertigrain Start' is an effective seed-soaking agent that resulted in improved spike length as compared to showed positive impact on plant growth in barley and linear trend of effectiveness was observed for concentrations of 'Fertigrain Start'. Hence, seed soaking with Fertigrain Start @3.0ml kg^{-1} seed and 2 irrigations would give optimistic results for spike length (Table 4).

Table 4. Spike length (cm) of barley as affected by Fertigrain Start and irrigation levels.

Fertigrain Start levels	Irrigation levels			Mean
	Soaking dose (control)	One irrigation (30 DAS)	Two irrigation (30 and 60 DAS)	
No seed soaking with Fertigrain Start (Control)	10.5	11.0	11.5	11.0 C
Seed soaking with Fertigrain Start @ 1.5 ml kg^{-1} seed	12.6	13.6	11.7	12.6 B
Seed soaking with Fertigrain Start @ 3.0 ml kg^{-1} seed	14.7	16.4	17.5	16.2 A
Mean	12.6	13.70	13.7	----

	Fertigrain levels (F)	Irrigation levels (I)	F x I
SE±	0.5096	0.5096	1.4884
LSD 0.05	1.0803	-	-
LSD 0.01	1.4884	-	-

Biological yield (kg ha^{-1})

The results in relation to biological yield ha^{-1} of barley as influenced by varied concentrations of amino acid fertilizer (Fertigrain start) as seed soaking agent and level of water stress.

The analysis of variance (Appendix-V) demonstrated significant ($P<0.05$) effect of seed soaking with Fertigrain Start, water stress levels and their interaction on biological yield ($P<0.05$) of barley.

The results showed that biological yield was remarkably higher (8002.40kg ha^{-1}) in plots sown with seed soaked with Fertigrain Start @3.0ml kg^{-1} seed; while reducing Fertigrain Start concentration to 1.5ml kg^{-1} seed caused a decrease in biological yield (7352.04kg ha^{-1}); and the lowest biological yield (6663.06kg ha^{-1}) was recorded in plots where the sowing of barley was done without seed soaking (Control). In case of water stress effects, the barley crop irrigated after 30 and 60 days of sowing (two irrigations) and after 30 days of sowing (one irrigation) produced biological yield of 7945.60 and 7400.91kg ha^{-1}, respectively and the lowest biological yield of 6641.00kg ha^{-1} was recorded in plots given soaking dose only and no subsequent irrigations (Control). The treatment interaction of Fertigrain Start @3.0ml kg^{-1} seed × 2 irrigations resulted in highest biological yield (8426.74kg ha^{-1}) and the interaction of No seed soaking × Control irrigation (soaking dose only) resulted in minimum biological yield (5762.45kg ha^{-1}). The 'Fertigrain Start' has been found to be efficient seed soaking agent at its higher concentration with increased biological yield as compared to lower concentrations. Hence, seed soaking with Fertigrain Start @3.0ml kg^{-1} seed and 2 irrigations would be an optimum treatment combination for maximizing biological yield in barley (Table 5).

Table 5. Biological yield (kg ha^{-1}) of barley as affected by Fertigrain Start and irrigation levels.

Fertigrain Start levels	Irrigation levels			Mean
	Soaking dose (control)	One irrigation (30 DAS)	Two irrigation (30 and 60 DAS)	
No seed soaking with Fertigrain Start (Control)	5762.4	6882.2	7344.5	6663.0 C
Seed soaking with Fertigrain Start @ 1.5 ml kg^{-1} seed	6625.3	7365.2	8065.5	7352.0 B
Seed soaking with Fertigrain Start @ 3.0 ml kg^{-1} seed	7625.2	7955.2	8426.7	8002.4 A
Mean	6671.0 C	7400.9 B	7945.6 A	--

	Fertigrain levels (F)	Irrigation levels (I)	F x I
SE±	24.189	24.189	41.897
LSD 0.05	51.278	50.632	88.817
LSD 0.01	70.651	70.651	122.37

Grains spike^{-1}

The data in regards to number of grains spike^{-1} of barley as affected by different concentrations of amino acid fertilizer (Fertigrain start) used as seed soaking agent and water stress level. The analysis of variance (Appendix-VI) described significant ($P<0.05$) influence of seed soaking with Fertigrain Start; while insignificant ($P>0.05$) for water stress levels and their interaction on grains spike^{-1} in barley. The grains spike^{-1} was significantly higher (33.767) when seed was soaked with Fertigrain Start @3.0ml kg^{-1} seed; followed by 1.5ml kg^{-1} concentration of 'Fertigrain Start' for seed soaking resulting 32.889 grains spike^{-1}; and the lowest grains spike^{-1} (31.478) were recorded in plots where the sowing of barley was done without seed soaking (Control). The water stress effects showed that the barley crop irrigated after 30 and 60 days of sowing (two irrigations) and after 30 days of sowing (one irrigation) produced 39.867 and 31.856 grains spike^{-1}, respectively and the lowest number of grains spike^{-1} (26.411) was noted in plots given soaking dose only and no subsequent irrigations (Control). The treatment interaction of Fertigrain Start @3.0ml kg^{-1} seed × 2 irrigations resulted in maximum grains spike^{-1} (44.633) and the interaction of No seed soaking × Control irrigation (soaking dose only) resulted in minimum grains spike^{-1} (25.30).

The results indicate that 'Fertigrain Start' amino acid fertilizer was an effectual seed-soaking agent @ 3.0ml kg^{-1} seed causing substantial improvement in grains spike^{-1} when compared with lower concentrations. Hence, seed soaking with Fertigrain Start @3.0ml kg^{-1} seed and two irrigations can be considered as adequate treatment for achieving higher values for this trait (Table 6).

Table 6. Grains spike^{-1} of barley as affected by Fertigrain Start and irrigation levels.

Sub-plot (Fertigrain start levels)	Main-plot (Irrigation levels)			Mean
	Soaking dose (control)	One irrigation (30 DAS)	Two irrigation (30 and 60 DAS)	
No seed soaking with Fertigrain Start (Control)	25.3	26.1	27.7	31.4 B
Seed soaking with Fertigrain Start @ 1.5 ml kg^{-1} seed	28.9	32.1	34.5	32.8 A
Seed soaking with Fertigrain Start @ 3.0 ml kg^{-1} seed	36.9	38.0	44.6	33.7 A
Mean	26.4	31.8	39.8	--

	Fertigrain levels (F)	Irrigation levels (I)	F x I
SE±	1.2548	2.2548	3.9054
LSD 0.05	2.0800	-	-
LSD 0.01	3.5858	-	-

Seed index (1000-grain weight, g)

The results regarding the seed index value of barley as influenced by varying concentrations of amino acid fertilizer (Fertigrain start) applied for seed soaking and water stress level. The ANOVA results suggested significant ($P<0.05$) response of crop for seed index to seed soaking with Fertigrain Start; water stress levels and their interaction. The seed index was significantly higher (47.60g) when seed was soaked with Fertigrain Start @3.0ml kg^{-1} seed; followed by 1.5ml kg^{-1} concentration of 'Fertigrain Start' for seed soaking resulting 45.322g seed index; and the minimum seed index (43.156g) was recorded in plots where the sowing of barley was done without seed soaking (Control). The water stress impacts indicated that the barley crop irrigated after 30 and 60 days of sowing (two irrigations) and after 30 days of sowing (one irrigation) produced 54.133 and 45.322g seed index value, respectively and the minimum seed index value (36.622g) was observed in plots given soaking dose only and no subsequent irrigations were applied (Control). The treatment interaction of Fertigrain Start @3.0ml kg^{-1} seed × 2 irrigations produced highest seed index value (59.567g) and the interaction of No seed soaking × Control irrigation (soaking dose only) produced lowest seed index value (33.967g).

It was noted that 'Fertigrain Start' amino acid fertilizer was a capable seed-soaking agent when applied @ 3.0ml kg^{-1} seed producing considerable improvement in seed index when compared with lower concentrations. Thus, for achieving barley grains of higher seed index value, the seed may be soaked with Fertigrain Start @3.0ml kg^{-1} seed and the crop may at least be irrigated two times during its growth period (Table 7).

Table 7. Seed index (1000-grain weight, g) of barley as affected by Fertigrain Start and irrigation levels.

Sub-plot (Fertigrain start levels)	Main-plot (Irrigation levels)			Mean
	Soaking dose (control)	One irrigation (30 DAS)	Two irrigation (30 and 60 DAS)	
No seed soaking with Fertigrain Start (Control)	33.9	35.2	40.6	43.1 B
Seed soaking with Fertigrain Start @ 1.5 ml kg^{-1} seed	44.9	48.5	42.5	45.3 A
Seed soaking with Fertigrain Start @ 3.0 ml kg^{-1} seed	50.6	52.2	59.5	47.6 A
Mean	36.6 C	45.3 B	54.1 A	

	Fertigrain levels (F)	Irrigation levels (I)	F x I
SE±	1.1784	1.1784	2.0410
LSD 0.05	2.4981	2.3212	4.3268
LSD 0.01	3.4418	3.4418	5.9614

Grain yield (kg ha^{-1})

The data pertaining to grain yield ha^{-1} of barley as influenced by different concentrations of 'Fertigrain start' (Amino acid fertilizer) applied for seed soaking and water stress level. The ANOVA results described significant ($P<0.05$) impact of seed soaking with Fertigrain Start and water stress levels; while insignificant ($P>0.05$) for their interaction on grain yield ha^{-1} in barley. The grain yield ha^{-1} was maximum (2730.00kg) when seed was soaked with Fertigrain Start @3.0ml kg^{-1} seed; followed by Fertigrain Start @1.5ml kg^{-1} seed with 2387.80 grain yield ha^{-1}; and the lowest grain yield ha^{-1} (1885.43kg) was obtained in plots where the sowing of barley was done without seed soaking (Control). The water stress impacts showed that the barley crop irrigated after 30 and 60 days of sowing (two irrigations) and after 30 days of sowing (one irrigation) produced grain yield of 2747.70 and 2374.43kg ha^{-1}, respectively and the minimum grain yield ha^{-1} (1881.10 kg) was found in plots given soaking dose only and no post-sowing irrigations were applied (Control). The treatment interaction of Fertigrain Start @3.0ml kg^{-1} seed × 2 irrigations resulted in maximum grain yield ha^{-1} (3056.70kg) and the interaction of No seed soaking × Control irrigation (soaking dose only) resulted in minimum grain yield ha^{-1} (1463.3 kg). It is evident from the results that 'Fertigrain Start' was an effective amino acid fertilizer for seed soaking when applied @ 3.0ml kg^{-1} seed to produce higher grain yields as compared to its lower concentrations. Hence, for achieving higher grain yields in barley, the seed may be soaked before sowing with Fertigrain Start @3.0ml kg^{-1} seed and at least two irrigations may be given during the entire cropping season (Table 8).

Table 8. Grain yield (kg ha^{-1}) of barley as affected by Fertigrain Start and irrigation levels.

Sub-plot (Fertigrain start levels)	Main-plot (Irrigation levels)			Mean
	Soaking dose (control)	One irrigation (30 DAS)	Two irrigation (30 and 60 DAS)	
No seed soaking with Fertigrain Start (Control)	1463.3	1823.3	2369.7	1885.4 C
Seed soaking with Fertigrain Start @ 1.5 ml kg^{-1} seed	1830.0	2516.7	2816.7	2387.8 B
Seed soaking with Fertigrain Start @ 3.0 ml kg^{-1} seed	2350.0	2783.3	3056.7	2730.0 A
Mean	1881.10 C	2374.4 B	2747.7 A	--

	Fertigrain levels (F)	Irrigation levels (I)	F x I
SE±	81.851	81.851	141.77
LSD 0.05	173.52	169.49	-
LSD 0.01	239.07	-	-

Harvest index (%)

The harvest index is calculated on the basis of grain quantity obtained out of biological yield. The results related to harvest index of barley as influenced by different concentrations of 'Fertigrain start' (Amino acid fertilizer) for seed soaking and water stress levels. The ANOVA results showed significant ($P<0.05$) effect of seed soaking with Fertigrain Start, water stress levels and their interaction on harvest index in barley.

The maximum harvest index (34.08%) was recorded in crop sown with seed soaked with Fertigrain Start @3.0ml kg^{-1} seed; followed by Fertigrain Start @1.5ml kg^{-1} seed with 32.24% harvest index; and the lowest harvest index (28.05%) was observed in plots where the sowing of barley was done without seed soaking (Control). The impact of water stress showed that the barley crop irrigated after 30 and 60 days of sowing (two irrigations) and after 30 days of sowing (one irrigation) recorded harvest index of 34.49 and 31.88%, respectively and the lowest harvest index (27.94%) was recorded in plots given soaking dose only and no post-sowing irrigations were applied (Control).

The treatment interaction of Fertigrain Start @3.0ml kg^{-1} seed × 2 irrigations resulted in highest harvest

index (36.27%) and the interaction of No seed soaking × Control irrigation (soaking dose only) resulted in lowest harvest index (25.39%). It is evident from the results that 'Fertigrain Start' was an effective amino acid fertilizer for seed soaking when applied @ 3.0ml kg^{-1} seed to result higher harvest index (Table 9).

Table 9. Harvest index (%) of barley as affected by Fertigrain Start and irrigation levels.

Sub-plot (Fertigrain start levels)	Main-plot (Irrigation levels)			Mean
	Soaking dose (control)	One irrigation (30 DAS)	Two irrigation (30 and 60 DAS)	
No seed soaking with Fertigrain Start (Control)	25.3	26.4	32.2	28.0 C
Seed soaking with Fertigrain Start @ 1.5 ml kg^{-1} seed	27.6	34.1	34.9	32.2 B
Seed soaking with Fertigrain Start @ 3.0 ml kg^{-1} seed	30.8	34.9	36.2	34.0 A
Mean	27.9 C	31.8 B	34.4 A	--

	Fertigrain levels (F)	Irrigation levels (I)	F x I
SE±	0.6785	0.6785	1.1752
LSD 0.05	1.4383	1.3972	2.4912
LSD 0.01	1.9817	1.9817	3.4324

Discussion

The crop productivity is primarily influenced by the seed emergence and uniform field emergence is essential to achieve high yield with respect to both quantity and quality in annual crops (Subedi and Ma, 2005). Apart from the good seedbed and other soil nutrients requirements, seed soaking or seed priming has proved to be an effective practice for rapid seed emergence and improved crop stand. Therefore, a field trial was conducted to investigate the effect of seed soaking with Fertigrain start (amino acid fertilizer) and moisture stress on germination, growth and yield of barley.

The present study showed that application of Fertigrain Start (amino acid fertilizer) for soaking of seed affected the growth and yield traits of barley significantly ($P<0.05$); while the water stress also significantly ($P<0.05$) affected all the growth and yield traits with the exception of grains $spike^{-1}$. The seed of barley crop soaked with Fertigrain Start @3ml kg^{-1} seed resulted in highest values for all the traits investigated with 164.33m^{-2} seed germination, 469.11 tillers m^{-2}, 87.66cm plant height, 16.256cm spike length, 8002.40kg biological yield ha^{-1}, 33.767 grains $spike^{-1}$, 47.60g seed index, 2730.00kg grain yield ha^{-1} and 34.03% harvest index. The lower concentration of Fertigrain Start (1.5ml kg^{-1} seed) resulted in reduced crop performance. Similar results have also been reported by (Naylor *et al.*, 1989), who soaked barley seed in a range of dilutions of chlormequat and monitored germination and growth of seedlings assessed for five weeks and reported that concentrations of chlormequat produced more leaves, more tillers, a greater leaf lamina area and a higher shoot dry weight. (Naeem and Muhammad, 2006) found that seed soaking with solution with different Na^{+} concentration and that more leaves were recorded when the solution containing higher concentrations of $CaSO^{4}$ (10mM). (Perveen *et al.*, 2008) reported that barley seeds were subjected to soaking in different solutions at varied concentrations. Sharp increase in the plant height was when $Mg(OH)_2$ and KOH solution were used for seed soaking at higher concentrations. (Balakhnina *et al.*, 2010) concluded that the barley seeds were soaked in aqueous M 4-hydroxyphenethyl to estimate its influence on seed germination and growth of seedlings. It was shown that the 4-HPEA was effective to stimulate seed germination, root and shoot growth, and biomass production, expressed to a greater extent in the early stage of plant development. (Abdolrahmani *et al.*, 2011) evaluated the effect of seed priming on growth trend and grain yield of barley and reported that the beneficiary effect of seed priming on growth and grain yield of barley were attributed to rapid seedling emergence and establishment, and consequently the optimum use of

light, soil moisture and nutrients by the plants developed from the primed seeds. (Anwar *et al.*, 2012) reported that twelve barely genotypes subjected to seed priming with 30mM NaCl or no seed priming and found that Seed priming had significant and positive impact on barley growth and yield. The higher concentrations of priming agent enhanced all the growth, yield and its related traits. (Golezani and Abdurrahmani, 2012) reported that beneficial effects of seed priming on yield and nutrient enrichment of barley grains were attributed to rapid seedling emergence and establishment, better winter survival, high ground green cover and consequently the best use of light, soil moisture and nutrients by the plants produced from the primed seeds.

Similarly, the barley crop receiving two irrigations after 30 and 60 days of sowing produced 140.22m^{-2} seed germination, 422.67 tillers m^{-2}, 95.55 cm plant height, 13.70cm spike length, 7945.60 kg biological yield ha^{-1}, 39.867 grains $spike^{-1}$, 54.133 g seed index, 2747.70 kg grain yield ha^{-1} and 34.49% harvest index. The crop given only one irrigation after 30 days of sowing and no post-sowing irrigation (only soaking dose) ranked 2nd and 3rd, respectively for all the growth and yield traits. It was concluded that the barley seed treatment (seed-soaking) with Amino acid fertilizer (Fertigrain Start) proved to be most effective to improve grain yield (2747.70kg ha^{-1}) when applied @3.0 ml kg^{-1} seed and the subsequent crop was irrigated two times after 30 and 60 days of sowing produced higher yields (2730kg ha^{-1}) than the crop irrigated once or kept on soaking dose only. However, the farmers are suggested for seed soaking with Fertigrain Start @ 3.0ml kg^{-1} seed and apply at least 2 irrigations for achieving higher barley grain yields. These results are in agreement with those of (Jang *et al.*, 2013) who studied the effects of deficit irrigation on the growth and yield of spring wheat and reported crop sensitive to water deficit, especially at the booting to grain-filling stages, but was not significantly affected by saline irrigation and the combination of the two factors. The results demonstrated that 300-mm irrigation water with a salinity of less than 3.2dS/m is suitable for wheat fields in the study area (Khaliliaqdam *et al.*, 2013) evaluated the impacts of various Salicylic Acid (SA) concentrates on some agronomical traits of barley when used as seed soaking agent. However, salicylic acid alleviated the adverse effect on grain yield and harvest index. Priming seeds with salicylic acid enhanced grain yield (5kg/ha/100µmol SA) until 1150µmol SA and then yield significantly decreased (6 kg/ha/100 µmol SA).

On the other hand, optimum grain yield was obtained in 1150µmol SA. Similarly, harvest index considerably upgraded as increasing in salicylic acid to circle point: 1252µmol SA. It seems border line of 1150 to 1252 can be considered as a suitable level for seed priming of barley if target is grain yield. (Tabatabaei *et al.*, 2013) reported positive impact of seed priming on seed germination, seedling growth and physical productivity indices of barley under water stress conditions due to seed priming with PEG (Polyethylene 6000mw).

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