

Response of Barley (*Hordeum vulgare* L.) Plants to Foliar Fertilizer with Different Concentrations of Hoagland Solution

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ABSTRACT

This experiment was conducted in pots with a randomized complete design to study the effects of foliar application with Hoagland's solution (0, 1/4, 1/2, 3/4 and full strength) on some morphological, physiological and yield characters of barley cv. Towetha. Both 1/4 and 1/2 strength treatments showed significant increase in all morphological (height of plant, leaves number, flag leaf area, tiller numbers, shoot dry weight), physiological (chlorophyll a, b and total chlorophyll, total nitrogen and total protein) and yield characters (number of spikes/plant, 100-grains weight and grain yield/plant) compared with the control treatment. It is concluded that barley cultivar gave a clear response to foliar application with Hoagland's solution and the half-strength Hoagland's solution was the preferred nutrient solution evaluated in this research.

Keywords: *Hordeum vulgare*, Foliar application, Hoagland's solution, Barley.

استجابة محصول الشعير (*Hordeum vulgare* L.) الى التسميد الورقي بمحلول هوكلاندي بتركيزات مختلفة

المخلص

أجريت هذه التجربة في السنادين وفي التصميم العشوائي الكامل لدراسة تأثير الرش الورقي بمحلول هوكلاندي بقرى صفر، 4/1 و 2/1 و 4/3 و قوة كاملة في بعض الصفات المظهرية والفسلجية وفي صفات الحاصل لمحصول الشعير صنف تويثا. كلتا القوتين 4/1 و 2/1 أظهرتا زيادة معنوية في جميع الصفات المظهرية المدروسة المتمثلة بارتفاع النبات، عدد الاوراق، مساحة ورقة العَلم، عدد الاشطاء والوزن الجاف للمجموع الخضري، وفي الصفات الفسلجية والتي شملت كلوروفيل أ و ب والكلوروفيل الكلي، النتروجين الكلي والبروتين الكلي وكذلك في صفات الحاصل ومكوناته المتمثلة بعدد السنابل / نبات، وزن 100 حبة وحاصل الحبوب للنبات الواحد مقارنة بمعاملة السيطرة. استنتج من الدراسة بأن محصول الشعير صنف تويثا قد استجاب بصورة واضحة الى الرش الورقي بمحلول هوكلاندي، وان محلول هوكلاندي بنصف قوته هو المحلول المغذي المفضل الذي تم تقييمه في هذا البحث.

INTRODUCTION

Barley (*Hordeum vulgare* L.) from Gramineae (Poaceae) family is grown as a commercial crop in many developing countries, is assumes the fourth position in total cereal production in the world after wheat, rice, and maize (Naghahi and Asgharipour, 2011). Barley is considered the very important and necessary cereal crops for the life of the world societies especially Iraq. It is strategic crop planted in relatively large areas and its output is related to food security of almost all the developing countries including Iraq. In addition, barley is playing important role of international trade, where the world reports are indicated that food shortages are basically attributed to the lack of

wheat and barely production. In Iraq, the total arable land is about 48 million donum, while only about 23 million donum is exploited (48%). About 47% of the total exploited arable land is planted by the two cereal crops: wheat and barley (Al-Obaidy, 2012).

Plant nutrition is one of the most important factor that increases plant production. Mineral nutrition alone has contributed significantly to increase crop yields during the 20th century, 50% of the increase in crop yields worldwide during the 20th century was due to application of chemical fertilizers. They also stated that during the 21st century, the essential plant nutrients would be the single most important factor limiting crop yields, especially in developing countries. A balanced fertilization program with macro and micronutrients in plant nutrition is very important in the production of high yield with high quality products (Sawan *et al.*, 2001). In most regions of the world the use of chemical fertilizers is very unbalanced and is not based on plants requirement. Each element in proper plant nutrition should be available enough for plants, and balance and respect the ratio between used nutrients is also important (Alloway, 2008). Qualitative and quantitative plant products can only be achieved if they are combined with proper plant nutrition. Besides the three macro elements (N, P, and K) essential microelements are inevitable. Micronutrient deficiency is widespread in many Asian countries due to the calcareous nature of soils, high pH, low organic matter, salt stress, continuous drought, high bicarbonate content in irrigation water, and imbalanced application of NPK fertilizers (Ahmadikhah *et al.*, 2010). During the last decades, foliar fertilization of nutrients has become an established procedure to increase yield and improve the quality of crop products (Fageria *et al.*, 2009). This procedure can also improve nutrient utilization and lower environmental pollution through reducing the amount of fertilizers added to soil (Abou El-Nour, 2002). On the other hand, foliar feeding of a nutrient not only an addition channel of nutrients but also a mean of regulating roots absorption by such plants (Ahmad *et al.*, 2006).

The present study was undertaken to investigate the response of barley cultivar Towetha to foliar application with different levels of Hoagland solution.

MATERIALS AND METHODS

Greenhouse experiment was carried out in College of Education, University of Salahaddin - Erbil during the period from December 15, 2011 to April 30, 2012. The soils were air-dried, grounded and passed through a 2-mm sieve. The soil portions were uniformly packed in plastic pots of 30-cm diameter and 30-cm height at a rate of 8 kg soil per pot. Physical and chemical properties of the used soils are shown in Table (1). The pots were brought to field capacity prior to sowing the seeds. Soil moisture status was maintained by frequently weighing the pots, and the amount of water equal to the weight loss was added. Six seeds of Barley (*Hordeum vulgare* L.) cv. Towetha were sown in each pot. One week after planting, seedlings were thinned to two vigorously growing plants per pot. All pots received 75mg P/kg soil, 75 mg K/ kg soil (as (KH_2PO_4) containing 22.70 %P and % 28.60 K). and 75mg N/kg soil (as NH_4NO_3 , 33.5 % N). Application of K and P fertilizer were done in a form of water solution added in the first irrigation. Nitrogen fertilizer was added in three equal doses, at 1st, 4th and within the 9th irrigation, respectively. Irrigation intervals were 4 days to maintain the soil moisture content at the field capacity by frequently weighing the pots, and the amount of water equal to the weight loss was added.

Water solutions of Hoagland plus surfactant [Tween 20 (Polyoxyethylene Sorbitan Monolaurate), 10 ml l^{-1})] were prepared (Table 2), then seedlings were sprayed twice after 40 and 50days from sowing (at tillering stage). Foliar treatments were: (i) distilled water (ii) 1/4 strength Hoagland's solution (iii) 1/2 strength Hoagland's solution (iv) 3/4 strength Hoagland's solution and, (v) full strength Hoagland's solution. Hoagland's solution of 1/4, 1/2 and 3/4 strengths were prepared from full strength Hoagland's solution by dilution. The plants were sprayed with solutions at the early morning hours by small handed-sprayer that the control plants were sprayed with

distilled water and the volume of the spray solution has to cover the plant foliage completely till drip. During spraying, each pot was surrounded by a portable wood barrier to prevent solution drift into adjacent pot. The experimental design was laid out in a randomized complete design with four replications.

The plant height, number of tillers and leaves, flag leaf area, shoot dry weight, leaf chlorophylls, total nitrogen and crude proteins were measured after 100days from sowing. The flag leaf area was measured by Stickler's equation (Stickler *et al.*, 1961) as given below:

$$\text{Leaf area (cm}^2\text{)} = L \times B \times 0.747$$

Where, L = length of leaf, B = Breadth of leaf

The chlorophylls *a* and *b* were determined according to the method of Arnon (1949), and calculated by the following formulae:

$$\text{Chl } a = [12.7 (\text{OD } 663) - 2.69 (\text{OD } 645)] \times V/1000 \times W$$

$$\text{Chl } b = [22.9 (\text{OD } 645) - 4.68 (\text{OD } 663)] \times V/1000 \times W$$

V = volume of the extract (mL)

W = weight of the fresh leaf tissue (g)

Plant shoots were dried in an electric oven with drift fan at (70°C) for 72hrs till constant dry shoot weight. The determination of total nitrogen was carried out according to micro- Kjeldahl method and the crude proteins were calculated by multiplying the total nitrogen percent by the factor of 5.7 (AOAC, 1995). At harvest, number of spikes/plant, number of grains/plant, 100-grains weight (g) and grain yield/ plant (g) were determined. The results were analyzed statistically using SPSS and the mean of treatments were compared using Fischer's Least Significant Differences (L.S.D) at the probability of $p \leq 0.05$ (Sendecor and Cochran, 1989).

Table 1: Some Physical and chemical properties of the soils used in the experiment

Sand%	69.10
Silt%	23.22
Clay%	7.68
Soil Texture	Sandy loam
Organic matter%	0.89
EC (dSm-1at 25 °C)	0.38
pH	7.65
Total nitrogen%	0.06
Available Phosphorus (mg Kg-1 soil)	1.03
Soluble Potassium (mg Kg-1 soil)	22.21

Table 2: Composition of Hoagland media full strength (100%) used in this study (Kittiwongwattana and Vuttipongchaikij, 2013)

Nutrient	mgL ⁻¹
MgSO ₄ .7H ₂ O	505.5
KH ₂ PO ₄	492.74
NH ₄ NO ₃	136.09
CaNO ₃	820.45
H ₃ BO ₃	2.86
Na ₂ MoO ₄ .2H ₂ O	0.025
MnSO ₄ .H ₂ O	0.05
MnCl ₂ .4H ₂ O	1.81
ZnCl ₂	0.11
FeCl ₃ .6H ₂ O	0.27
Na ₂ EDTA	44.8

RESULTS AND DISCUSSION

Data presented in Table (3) show that foliar application of Hoagland's solution at 1/4 and 1/2 strength led to significant increases in morphological growth criteria of barley plants which included plant height, number of tillers, number of leaves, flag leaf area and shoot dry weight/plant compared to corresponding untreated plants after (100) days from sowing. Furthermore, half strength Hoagland's solution was the most effective treatment in increasing the mentioned growth parameters followed by 1/4 strength treatment. These results are partially agreed with those obtained by Malakouti (2000), Ahmad *et al.*, (2006), Ahmadikhah *et al.*, (2010) on wheat plants and Sultana *et al.*, (2008) on rice plants. Whereas, increasing Hoagland's solution strength to 3/4 and full strength had no significant effects. Hoagland and Arnon (1950) suggested that the presence of higher concentrations of nutrients did not increase biomass production. This result represents relatively higher nutrient utilization efficiency, as production occurred in a more diluted nutrient solution.

Elongation of cells and plant height is one of the most important acts of auxin and there is only one known natural auxin (Indol- 3-acetic acid) which has proven that this compound is made from Tryptophan amino acid (Mortazavaibak, 1998). Firouzi (2005) concluded that the reason of increase in leaf area was increase in length and width of leaves which could be because of zinc and nitrogen effect on cell dividing via auxin increasing. Shorrocks and Allowang (1988) said that copper affects nitrogen metabolism and then plant height will be increased via tryptophan and auxin producing. An increase in the shoot dry weight might be due to an increase in number of tiller and leaves, as well as leaf area leading to increase photosynthetic activity (Sultana *et al.*, 2001).

The effect of foliar spray with Hoagland's solution on the photosynthetic pigments in the leaves of barley plants after (100) days from sowing are shown in Table (4). Hoagland's solution significantly increased chl. a, chl. b and total chlorophyll recording maximum values at 1/2 strength. On the contrary, the content of such pigments were reversely changed using higher strengths of Hoagland's solution. These results agreed with those found by Mariotti *et al.*, (1996). They observed with adding magnesium and iron to spraying fertilizer, leaf area will be increased because of iron and magnesium roles in chlorophyll production and photosynthesis increasing. Ahmad *et al.*, (2006) observed that chlorophyll a, b, and carotenoids were increased due to complete foliar fertilizer compound and this effect may attribute to stimulation the biosynthesis of chlorophylls and delay leaf senescence.

In addition, foliar application of Hoagland's solution significantly increased total nitrogen and proteins in the leaves of barley plants after (100) days from sowing (table 4). The highest values of total nitrogen in the barley leaves were 15.61 and 15.75 mg g⁻¹ leaf D.wt and for total protein were 88.97 and 89.77 mg g⁻¹ leaf D.wt. respectively, were obtained by Hoagland's solution at the rates of 1/4 and 1/2 strength were significantly higher as compared with control (13.34 and 76.03) after 100 days from sowing. This result may be due to an increase in nitrogen content by foliar application of Hoagland's solution which consider as a building blocks in the synthesis of proteins.

Data presented in Table (5) show that foliar application of Hoagland's solution, especially at 1/4 and 1/2 strength resulted in the significant increases in yield and its components (i.e., number of spikes, grains number/plant, 100-seeds weight and grain yield per plant) compared to control plants. The maximum values of yield and its components were obtained as a result of foliar spray with Hoagland's solution at 1/2 strength. Whereas, increasing Hoagland's solution rates to 3/4 and full strength had no significant effects on yield and its components compared to control plants. These results are agreed with those obtained by Sultana *et al.*, (2001) on rice plants, Kinaci and Gulmezoglu (2007) on triticale, Ahmad *et al.*, (2006) and Ahmadikhah *et al.*, (2010) on drum wheat. Foliar use of macro and micro elements covered all needs of wheat and had the highest

effect on yield and its components. The increase in yield characteristics of wheat plants by using Hoagland's solution might be due to enhanced assimilation, nutrient uptake, nitrate reduction and photosynthesis, improved flow assimilates translocation transferring to grains which increased 100 grains weight and grain yield consequently (Malakouti, 2000).

Generally, such enhancement effect of foliar application with Hoagland's solution might be attributed to the combined favorable influence of their nutrients (N, P, K, Ca, Mg, Fe, Zn, Mn, Mo, B, Cu) on vegetative growth of plants that reflected on an increase in growth parameters, yield and chemical constituents of plants (Glass, 1989; Jones *et al.*, 1991). The requirement of macronutrients for plants is associated with their role in making up the bulk of the carbohydrates, proteins, and lipids of plant cells, whereas micronutrients mostly participate in the enzyme activation process of the plant (Rice, 2007). The micronutrients play roles in increasing growth and crop yield (Ahmadikhah *et al.*, 2010) and have prominent effects on dry matter, grain yield and straw yield in crop (Emami, 2005).

Table 3: Effect of different strengths of Hoagland's solution as foliar feeding on morphological growth characteristics of barley plants after (100) days from sowing.

Treatments	Plant height(cm)	Number of tiller/plant	Number of leaves/plant	Flag leaf area (cm ² plant ⁻¹)	Shoot dry wt. (g plant ⁻¹)
Control	58.54	5.60	14.40	55.29	3.38
1/4 strength Hoagland's solution	64.16	8.80	17.00	64.01	4.52
1/2 strength Hoagland's solution	69.30	9.20	18.40	68.30	5.11
3/4 strength Hoagland's solution	62.02	6.40	16.00	60.01	4.45
full strength Hoagland's solution	57.80	5.20	14.50	50.54	4.09
L.S.D (0.05)	3.18	2.05	1.89	6.31	1.12

Table 4: Effect of different strength of Hoagland's solution as foliar feeding on chlorophylls, total nitrogen and proteins content in leaves of barley plants after (100) days from sowing.

Treatments	Chlorophyll a (mg g ⁻¹ leaf F.wt.)	Chlorophyll b (mg g ⁻¹ leaf F.wt.)	Total Chlorophyll (mg g ⁻¹ leaf F.wt.)	Total nitrogen (mg g ⁻¹ leaf D.wt.)	Total proteins (mg g ⁻¹ leaf D.wt.)
Control	0.91	0.29	1.20	13.34	76.03
1/4 strength Hoagland's solution	1.22	0.39	1.61	15.61	88.97
1/2 strength Hoagland's solution	1.38	0.46	1.84	15.75	89.77
3/4 strength Hoagland's solution	1.13	0.33	1.46	15.00	85.50
full strength Hoagland's solution	0.99	0.32	1.31	13.55	77.23
L.S.D (0.05)	0.26	0.10	0.31	1.75	10.08

Table 5: Effect of different strength of Hoagland's solution as foliar feeding on yield and yield components of barley plants

Treatments	Number of spikes/plant	Spike length (cm)	Grains number/plant	100-seeds weight (g)	Grain yield (g)/plant
Control	5.20	11.80	94.66	5.44	5.16
1/4 strength Hoagland's solution	7.60	13.00	109.66	5.90	6.48
1/2 strength Hoagland's solution	7.80	14.80	120.33	6.40	7.71
3/4 strength Hoagland's solution	5.60	13.90	103.66	5.63	5.86
full strength Hoagland's solution	5.10	11.54	99.33	5.53	5.55
L.S.D (0.05)	2.13	n.s.	11.07	0.38	0.92

CONCLUSION

From the preceding results and discussion, it can be concluded that foliar application of barley plants with Hoagland's solution at rates of 1/4 and 1/2 strength stimulate the growth and yield of barley and both of 3/4 and full strengths were over doses.

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