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Effect of salinity irrigation and seaweed extracts on vegetative growth and productivity of Barley

Mohamed Abdalla Emhemmed Hussain

mohammed.hseen@su.edu.ly

[(1)] Plant Production Department, the Faculty of Agriculture, sirte University, Libya .

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Abstract:
A experiment was conducted at Abu Hadi area-Sirte city, during the winter season 2022-2023 to study the effect of salinity irrigation and seaweed extracts on vegetative growth and productivity of Barley (Hordeum vulgare, L.) cv., REHAN. The experiments were carried out in a split plot design with three replicates. Five salinity irrigation levels (control, 1000, 2000, 3000 and 4000 mg/l) were arranged in main plots and the other four seaweed extract (control, 2, 4 and 6 l/ha) were arranged in sub- sub plots. Each replicate contained 9 treatments. Studied characters were vegetative growth i.e. (plant height, number of tillers/m2, dry matter (g/m2), Total chlorophyll (SPAD), leaf area, (cm2) and yield and yield components (spike length (cm), spike weight (g), no. of grains/spike, 100- grain weight, grain yield (t/fed), biological yield (t/fed) and harvest index (%). Results showed that increasing salinity irrigation levels up to 4000 mg/l significantly decreased all vegetative growth were studied (plant height, number of tillers/m2, dry matter, total chlorophyll, leaf area) as compared to control treatment which recorded the higher values of this traits. On the other hand, seaweed extracts up to 6 l/ha recorded the highest values of all vegetative growth were studied (plant height, number of tillers/m2, dry matter, total chlorophyll, leaf area), as compared to control treatment which recorded the lowest values of this traits. In addition, increasing salinity irrigation levels up to 4000 mg/l significantly decreased yield and yield component i.e. spike length, spike weight number of grains/spike, 1000-grain weight, grain yield, biological yield and harvest index, as compared to control treatment which recorded the higher values of this traits, while seaweed extracts up to 6 l/ha recorded the highest values of spike length, spike weight number of grains/spike, 1000-grain weight, grain yield, biological yield and harvest index, as compared to control treatment which recorded the lowest values of this traits. The interaction between salinity irrigation and seaweed extracts was highly significant on all vegetative growth and yield and yield component were studied under this study.

Keywords: Barley (Hordeum vulgare L.), salinity irrigation levels, seaweed extracts, vegetative growth, yield and yield components.

تأثير الري بالملوحة ومستخلصات الطحالب البحرية في النمو الخضري والإنتاجية لنبات الشعير

*محمد عبدالله أمحمد حسين
* جامعة سرت ـ كلية الزراعة ـ قسم الإنتاج النباتي
mohammed.hseen@su.edu.ly *

ملخص البحث:
أجريت التجربة الحقلية بمنطقة أبو هادي – مدينة سرت خلال الموسم الشتوي 2022-2023 لدراسة تأثير الري بالملوحة ومستخلصات الطحالب البحرية في النمو الخضري والإنتاجية لنبات الشعير صنف الريحان. تصميم التجربة كان القطع المنشقة بثلاثة مكررات. تم ترتيب خمسة مستويات للري بالملوحة (الكونترول، 1000، 2000، 3000، 4000 مجم/لتر) في القطع الرئيسية وتم ترتيب المستويات الأربعة الأخرى لمستخلص الأعشاب البحرية (الكونترول، 2، 4 ، 6 لتر/هكتار) في القطع فرعية وتحتوي كل مكررة على 9 معاملات. الصفات المدروسة هي النمو الخضري (ارتفاع النبات، عدد الأشطاء/م2، المادة الجافة (جم/م2)،

الكلوروفيل الكلي (SPAD)، مساحة الورقة (سم2) والمحصول ومكونات المحصول (طول السنبلة (سم)، وزن السنبلة (جم)، عدد الحبوب/السنبلة، وزن 100 حبة (جم)، محصول الحبوب (طن/ فدان)، المحصول البيولوجي (طن/ فدان)، دليل الحصاد (%). أظهرت النتائج أن زيادة مستويات الري بالملوحة حتى 4000 مجم/ لتر أدت إلى انخفاض معنوي في جميع صفات النمو الخضري المدروسة (ارتفاع النبات، عدد الأشطاء /م2، المادة الجافة، الكلوروفيل الكلي، المساحة الورقية) مقارنة بمعاملة الكونترول التي سجلت أعلى القيم لهذه الصفات. من ناحية أخرى سجلت مستخلصات الطحالب البحرية بمعدل 6 لتر/هكتار أعلى القيم لجميع صفات النمو الخضري التي تمت دراستها (ارتفاع النبات، عدد الأشطاء /م2، المادة الجافة، الكلوروفيل الكلي، المساحة الورقية)، مقارنة بمعاملة الكونترول التي سجلت أقل القيم لهذه الصفات. بالإضافة إلى ذلك، أدت زيادة مستويات الري بالملوحة حتى 4000 مجم/لتر إلى انخفاض ملحوظ في المحصول ومكونات المحصول (طول السنبلة، ووزن السنبلة، وعدد الحبوب/السنبلة، ووزن 1000 حبة، ومحصول الحبوب، والمحصول البيولوجي، ودليل الحصاد، مقارنة بمعاملة الكونترول والتي سجلت أعلى القيم لهذه الصفات، بينما سجلت مستخلصات الطحالب البحرية بمعدل 6 لتر/هكتار أعلى القيم لطول السنبلة ووزن السنبلة وعدد الحبوب/سنبلة ووزن 1000 حبة ومحصول الحبوب والمحصول البيولوجي ودليل الحصاد، مقارنة بمعاملة الكونترول التي سجلت أقل القيم لهذه الصفات. كان للتفاعل بين الري بالملوحة ومستخلصات الطحالب البحرية عالي المعنوية على جميع صفات النمو الخضري والمحصول ومكونات المحصول التي تمت دراستها في هذه الدراسة.

INTRODUCTION

Barley (*Hordeum vulgare*, L.), an annual grain crop with a cool season and quick growth, is a member of the poaceae family. It can be used as a cover crop to increase soil fertility and as fodder **(Ghanbari *et al.*, 2012).** An estimated 141.7 million tonnes of barley are produced worldwide **(USDA, 2017).**

Among the cereal crops with the greatest economic importance is barley. It is generally utilized as a raw material in the manufacturing of feed. The demand for grain and fodder grains rises in response to an increase in meat output **(FAOSTAT, 2018).** It is the fourth-largest cereal crop in the world after maize, wheat, and rice. It is one of the oldest agricultural crops in the world and among the first to be domesticated. It makes up 7% of the world's total grain production **(Arebu, 2022).**

In addition, it is among the oldest agricultural crops in the world, one of the first domesticated grains, and the fourth-biggest cereal crop globally after rice, wheat, and maize. It makes up 7% of the world's total cereal production **(Yimer, 2022).**

Due to its resilience to difficult and unfavourable environmental conditions, barley is one of the most important and tolerant crops **(Singh and Upadhyaya, 2015).** Due to its unique genetic makeup, barley can withstand a wide range of global climates and is typically grown in temperate and subtropical regions **(Pardo *et al.*, 2022).**

Barley is a commercial crop grown in many nations. The top five global producers of barley are the European Union, Russia, Canada, the United States, and Argentina. Of these, the European Union produces the most barley, estimated at 20.5 million tonnes, followed by the Russian Federation at about 8 million tonnes. The estimated barley production of Canada, the United States, and Argentina was 7.3, 3.1, and 2.8 million tonnes, respectively **(USDA, 2017).**

Among the small-grain cereals, barley is very resilient to abiotic conditions like drought and salinity. Because of its simpler genome than other cereal crops, it is frequently used as a model plant to understand mechanisms of salt-tolerance **(Mwando *et al.*, 2020; Pour-Aboughadareh *et al.*, 2020).**

According to the FAO report, 504,000 hectares and around 3.50 tonnes of harvested barley are projected to be produced globally in 2020 **(FAO, 2022).** The cereal's kernels, being whole grains, offer a range of health advantages including calcium, phosphorus, fibre, protein, minerals, and different kinds of vitamins **(Singh *et al.*, 2020; Fatemi *et al.*, 2022).** Barley is one cereal that can withstand high salinity stress levels, although salinity still has a significant impact on its performance and worldwide output **(Jadidi *et al.*, 2022).**

Consideration is given to stress as the primary factor limiting agricultural production in semi-arid and arid settings. Rainfall patterns in these semi-arid, dry regions are occasionally inconsistent with crop requirements, leading to the development of products that are affected by either a brief or protracted drought **(Alinezhad *et al.*, 2013).**

Salt reduces yield in semi-arid and arid regions. Alternative sources of irrigation water are being sought after due to the growing demand. The salt of seawater was once thought to make it unsuitable for irrigation. However, in some circumstances, using this water to cultivate crops can be fruitful. According to **Sadak *et al.* (2015),** amino acids are a well-known biostimulant that promotes plant growth and yield while also considerably reducing the damage brought on by abiotic stressors.

Among the main factors affecting agricultural ecosystems in dry and semi-arid parts of the world are soil salinity, soil sterility, and freshwater scarcity **(Mrema *et al.*, 2022).** More than 955 million hectares (mha) of land are predicted to be affected by salt by the United Nations Food and Agriculture Organisation, with around 77 mha being ascribed to secondary salinization **(Srinivasan *et al.*, 2022).**

Due to increased salt deposition in the root zone, which alters the pH of the soil and makes some nutrients unavailable for plant absorption, soil salinization interferes with the interactions between roots and soil **(Phogat *et al.*, 2020; Haj-Amor *et al.*, 2022).** As a result, crop productivity and the yield of plants susceptible to salt are declining. However, another significant issue that livestock farmers worldwide are dealing with as a result of climate change is freshwater scarcity in dry and semi-arid places **(Matope *et al.*, 2020; Singh and Chudasama, 2021).** Due to the use of salty subsurface water for irrigation, this has exacerbated land degradation and biodiversity loss. As a result, crop yields of salt-sensitive forages required for animal nutrition have decreased **(Sheikh *et al.*, 2021).**

Reduced transpiration, photosynthesis, and other biochemical processes linked to plant growth, such as crop productivity and plant development, were the results of salinity stress **(Tiwari *et al.*, 2010).** One benefit of using saline irrigation water is that it can reduce the amount of fresh water needed for crops that can withstand salt. However, salinity lowers yield and has an impact on crops based on its level during important growth stages. According to **Mojid *et al.* (2012),** irrigation with saline water must therefore be adjusted to the proper level for the particular crops.

One of the main abiotic stresses that lowers crop productivity and plant growth worldwide is salinity **(Kausar *et al.*, 2013).** According to **Radi *et al.* (2013),** excessive chlorophyllase activity, a decrease in carboxylase, and suppression of chlorophyll synthesis were the reasons for the lowest photosynthetic performance at higher salt levels.

However, under slat stress, plants accumulated proline at a faster pace **(Azam *et al.*, 2012).** Due to a high electron leakage towards O2 during photosynthetic and respiratory activities, salinity and drought cause oxidative stress in plant cells, which ultimately results in cell death **(Fayez and Bazaid, 2014).**

Drought stress lowers barley grain yield by having a negative impact on yield and yield components that are measured at different stages of the crop's growth, such as number of plants per unit area, number of spikes and kernels per plant or unit area, and single grain weight **(Beigzadeh *et al.*, 2013; Haddadin, 2015).**

Reduced water content, stomata closure, and decreased cell enlargement and growth are the hallmarks of drought. Leaf senescence, an age-dependent deterioration process, is also linked to drought, ensuring the translocation of nutrients from older leaves to developing tissues and seeds **(Temel *et al.*, 2017).**

Most crops, including barley, have a much lower production potential when exposed to salinity, which can also cause oxidative stress, ion-specific stress, osmotic effects disruption, and ionic imbalance **(Tabatabaei and Ehsanzadeh, 2016).** Early in their growth, field crops are particularly vulnerable to osmotic stress **(Yadav *et al.*, 2019).** According to **Ahmed *et al.* (2019),** salinity can hinder or even completely stop seeds from germinating, especially radicle growth **(Kshetrimayum *et al.*, 2017).**

Among the organic sources utilized in agricultural production are seaweed extracts; they should be used as a supplement rather than a replacement for fertilizers **(Abdul-Jabar *et al.*, 2012; Agricultural Statistics, 2020).** Due to the harm that manufactured chemical fertilizers cause to human health, the environment, and the economy, there is currently a global trend to use less of them.

One natural alternative is the use of marine algae extracts, which are inexpensive, non-toxic, and do not pollute the environment **(Al-Juthery *et al*., 2018; Al Hasnawi *et al*., 2020).** It contains multiple groups of plant hormones that promote growth, such as auxins and cytokinins, at least two types of gibberellins, 3GA and 7GA, a number of major nutrients, like Mg, N, and K, and micro-elements, like Co, Bo, Cu, Mn, and Zn. When used in low concentrations, it is also an encouraging material for plant growth and contributes to most of the important physiological functions of any crop **(Al-Maliki *et al*., 2019).**

According to **Margal *et al*. (2023),** seaweed extracts are biostimulants that are extracted from seaweed, particularly brown and red algae, and which can improve soil health, increase crop stress resistance, and encourage crop growth and quality.

Thus, this work aimed study the effect of salinity irrigation and seaweed extracts on vegetative growth and productivity of Barley c.v. REHAN.

MATERIALS AND METHODS

The field experiment was conducted at Abu Hadi area-Sirte city, during the winter season 2022-2023 to study the effect of salinity irrigation and seaweed extracts on vegetative growth and productivity of Barley c.v. REHAN. The experiment consisted of seven treatments arranged in a Randomized Completely Block Design (RCBD) with two factors with three replicates for each treatment.

The treatments of this experiment could be summarized as follows:

A) Salinity irrigation (mg/l)

- Control
- 1000
- 2000
- 3000
- 4000

B) Seaweed extract (l/ha)

- Control
- 2
- 4
- 6

Data recorded

A) Vegetative growth

- Plant height (cm).
- Number of tillers/m^2
- Dry matter (g/m^2)
- Total chlorophyll (SPAD) Chlorophyll content was measured in the early morning before mid-day using an MC-100 chlorophyll meter from Apogee Instruments, Inc, Utah, USA and data was expressed as SPAD averages.
- Leaf area (cm^2).
  Leaf area was calculated as shown below according to the formulae of **Elsahookie and Cheyed (2014).**
  Leaf area = L ∗ W ∗ C
  where L is the leaf length, W is the leaf width, and C is the constant (0.75). The leaf area index (LAI) was calculated according to the formulae below
  LAI = leaf area/plot area

B) Yield and yield components

- Spike length (cm)
- Spike weight (g)
- No. of grains/spike
- 100- grain weight.
- Grain yield (t/fed)
- Biological yield (t/fed)
- Harvest index(%)

Statistical analysis:

Results of the measured parameters were subjected to computerized statistical analysis using SAS statistical software version 9.0, for analysis of variance (ANOVA) and means of treatments were compared using LSD at 0.05 according to **Snedecor and Cochran (1990).**

RESULTS AND DISCUSSION

A) Vegetative growth

Results presented in **Table (1) and Fig. (1)** showed that effect of salinity irrigation on vegetative growth characters i.e. plant height, number of tillers/m^2, dry matter, total chlorophyll and leaf area index of barely c.v. REHAN. However, results showed that increasing salinity irrigation levels decreasing vegetative growth studied which salinity irrigation levels up to 4000 mg/l recorded the lowest values of plant height (51.42 cm), number of tillers/m^2 (292/m^2), dry matter (420.33 g/m^2), total chlorophyll (30.20 SPAD) and leaf area index (3.02 cm^2), as compared to control treatment which recorded the highest value of plant height (98.11cm), number of tillers/m^2 (372/m^2), dry matter (646.25 g/m^2), total chlorophyll (52.20 SPAD) and leaf area index (5.10 cm^2), respectively.

On the other hand, results cleared that effect of seaweed extract on vegetative growth characters i.e. plant height, number of tillers/m^2, dry matter, total chlorophyll and leaf area index of barely c.v. REHAN. However, results showed that increasing seaweed extract levels increasing vegetative growth studied which seaweed extract levels up to 6 l/ha recorded the highest values of plant height (102.11cm), number of tillers/m^2 (399.60/ m^2), dry matter (642.80 g/m^2), total chlorophyll (52.73 SPAD) and leaf area index (5.09 cm^2), followed by seaweed extract at 4 l/ha plant height (97.55 cm), number of tillers/m^2 (387.39/ m^2), dry matter (566.66 g/m^2), total chlorophyll (44.40 SPAD) and leaf area index (4.38 cm^2), as compared to control treatment which recorded the lowest value of plant height (57.08 cm), number of tillers/m^2 (324.12/ m^2), dry matter (466.57 g/m^2), total chlorophyll (33.52 SPAD) and leaf area index (3.35 cm^2), respectively.

The metric of number of tillers/m2 was not considerably impacted by rising salinity. This result might be explained by the barley crop's high regulatory efficiency when exposed to salinity. Salinity was found to decrease spike length, number of spikelets per spike, number of grains per spikelet, 100 grain weight, and grain production per plant by **Akram *et al.* (2002).** An increase in salinity considerably lowered the rate of photosynthesis, which is in line with findings by **Francois *et al.* (1994).**

This discrepancy could be explained by genetic differences amongst barley cultivars as well as a reduction in effective leaf area during photosynthesis, which lowers the amount of light energy absorbed and transformed into chemical energy stores. This increases the proportion of florets that fail, which lowers the number of grains/spike. Moreover, the produced material was insufficient during the pre-flowering phase **(Al-Saadawi and Dahesh, 2000).**

Its mechanisms for preserving the ionic balance within the plant and its capacity to filter out harmful salt elements while preserving beneficial elements like potassium may be the cause of this. This will be evident in the crop's good growth performance and increased yield **(Ayreen *et al.*, 2006).**

The increase could be attributed to the good vegetative growth that seaweed extract-treated plants displayed. This could be because the extract contains essential nutrients for growth, like nitrogen, which has a wide range of effects on increasing the vital activities in the plant and will therefore increase It is absorbed by the plant's growth, indicating that it is growing more, which increased the quantity of spikes. This outcome aligns with the findings of **Leila *et al.* (2018).**

Seaweeds have long been recognised for their ability to promote plant development in agriculture. Seaweed extracts are rich in phytohormones that play important roles as biostimulants, elicitors for abiotic stress, and enhance plant productivity. These phytohormones include auxins, cytokinins, gibberellins, abscisic acid, and ethylene, as well as amino acids, vitamins, betains, polyamines, carrageenans, polysaccharides, and sterols. Seaweed saps are well known for their antibacterial strength and capacity to shield plants from invading natural elements, in addition to being growth stimulants. Generally speaking, seaweed extracts have the ability to alter the physiological and biochemical processes involved in plant development and nutrient uptake in agriculture **(Chaturvedi *et al.*, 2022).**

Treatments	Plant height (cm)	No. of tillers/m^2	Dry matter (g/m^2)	Total chlorophyll (SPAD)	Leaf area index (cm^2)
A) Salinity irrigation (mg/l)					
Control	98.11	372	646.25	52.20	5.10
1000	91.99	360	579.10	47.50	4.59
2000	87.88	349	510.50	40.00	3.95
3000	71.22	311	473.22	35.60	2.92
4000	51.42	292	420.33	30.20	3.02
LSD (0.05)	**5.08**	**3.33**	**20.13**	**3.82**	**0.34**
B) Seaweed extract (l/ha)					
Control	57.08	324.12	466.57	33.52	3.35
2	79.05	345.21	525.27	39.52	3.24
4	97.55	387.39	566.66	44.40	4.38
6	102.11	399.60	642.80	52.73	5.09
LSD (0.05)	**5.64**	**3.6963**	**22.34**	**4.24**	**0.38**
Interactions (A X B)	**	**	**	**	**

Table (1): Effect of salinity irrigation and seaweed extract on vegetative growth of barley c.v. REHAN.

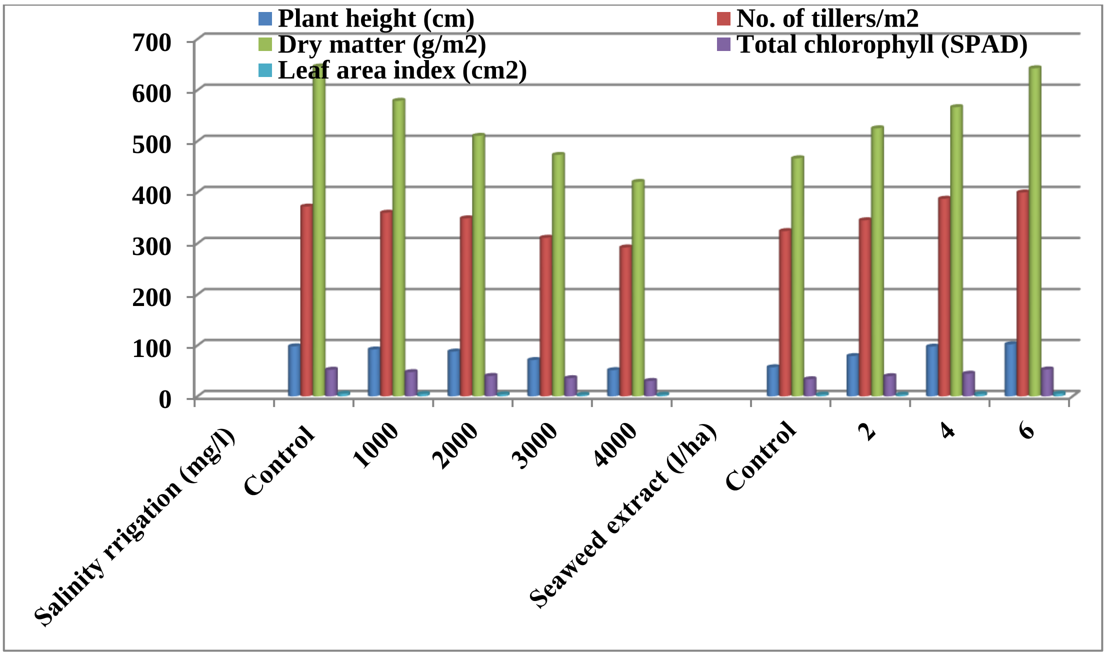

Fig. (1): Effect of salinity irrigation and seaweed extract on vegetative growth of barley c.v. REHAN

B)Yield and yield components

Results presented in **Table (2) and Fig. (2)** showed that effect of salinity irrigation on yield and yield components of characters i.e. spike length, spike weight, number of grains/ spike, 1000-grain weight, grain yield, biological yield and harvest index of barely c.v. REHAN. However, results showed that increasing salinity irrigation levels decreasing yield and yield components were studied which salinity irrigation levels up to 4000 mg/l recorded the lowest values of spike length (5.36 cm), spike weight (2.71 g), number of grains/ spike (30.21), 1000-grain weight (38.60 g) grain yield (1.91 g), biological yield (4.36 g), and harvest index (43.81%), as compared to control treatment which recorded the highest value of spike length (7.77 cm), spike weight (3.85 g), number of grains/ spike (45.88), 1000-grain weight (55.72 g) grain yield (2.71g), biological yield (6.53 g), and harvest index (41.50 %), respectively.

On the other hand, results cleared that effect of seaweed extract on yield and yield components characters i.e. spike length, spike weight, number of grains/ spike, 1000-grain weight, grain yield, biological yield and harvest index of barely c.v. REHAN. However, results showed that increasing seaweed extract levels increasing yield and yield components studied which seaweed extract levels up to 6 l/ha recorded the highest values of spike length (8.62 cm), spike weight (4.27g), number of grains/ spike (50.93), 1000-grain weight (61.85 g) grain yield (3.01 g), biological yield (7.25 g), and harvest index (46.07%), followed by seaweed extract at 4 l/ha spike length (7.91 cm), spike weight (3.89 g), number of grains/ spike (47.23), 1000-grain weight (58.12g) grain yield (2.78 g), biological yield (6.49 g), and harvest index (47.44%), as compared to control treatment which recorded the lowest value of spike length (6.96 cm), spike weight (3.21g), number of grains/ spike (37.97), 1000-grain weight (48.06g) grain yield (2.40g), biological yield (6.01g), and harvest index (44.32%), respectively.

The values of crop and field water productivity clearly increased as the amount of seaweed extract sprayed increased, and they clearly decreased as the amount of depletion increased. The above data indicates that applying varying concentrations of marine algae extract to crops and fields has a notable effect on crop and field water productivity values. This is because the application of marine algae extract influences the depth at which actual water consumption occurs, which in turn increases wheat grain yield. The effect of applying marine algae extract at a concentration of 8 ml L-1 was greatest because it enhanced the soil's capacity to retain moisture and enhanced wheat According to **Rioux *et al.* (2007),** increasing the level of depletion causes the plant to be exposed to water stress, which lowers grain yield values but increases water consumption. As a result, the values of crop productivity and field water productivity decreased.

This drop is explained by the seaweed extract that was added, which increases the permeability of water in the soil and causes salts to seep from the surface down to the depths. Furthermore, because the soil is exposed to extended droughts, the depletion rate of salt rises as this proportion rises **(Jassem and Muhammad, 2010).**

Treatments	Spike length (cm)	Spike weight (g)	No. of grains /spike	1000-grain weight	Grain yield (t/fed)	Biological Yield (t/fed)	Harvest index (%)
A) Salinity irrigation (mg/l)							
Control	7.77	3.85	45.88	55.72	2.71	6.53	41.50
1000	7.13	3.50	42.55	52.36	2.50	5.85	42.74
2000	6.94	3.02	38.99	47.00	2.41	5.73	42.06
3000	6.27	2.89	34.21	43.30	2.16	5.41	39.93
4000	5.36	2.71	30.21	38.60	1.91	4.36	43.81
LSD (0.05)	**1.10**	**0.72**	**2.97**	**1.52**	**0.24**	**0.48**	**2.61**
B) Seaweed extract (l/ha)							
Control	6.96	3.21	37.97	48.06	2.40	6.01	44.32
2	7.70	3.35	43.28	52.17	2.68	6.36	46.69
4	7.91	3.89	47.23	58.12	2.78	6.49	47.44
6	8.62	4.27	50.93	61.85	3.01	7.25	46.07
LSD (0.05)	**1.22**	**0.80**	**3.30**	**1.69**	**0.27**	**0.53**	**2.90**
Interactions (A X B)	**	**	**	**	**	**	**

It's possible that the limited number of grains per spike contributed to the grain's increased weight in the comparative treatment. The outcomes were not the same as this one **(Shahbazi *et al.*, 2015).** Positive results were seen in the rise in grain yield **(Al-Hasany *et al.*, 2019).** Applying a seaweed extract spray at a greater concentration has the potential to enhance grain yield since it improves the quantity of grains in each spike as well as the number of spikes per square meter of land.

Table (2): Effect of salinity irrigation and seaweed extract on yield and yield components of barley c.v. REHAN.

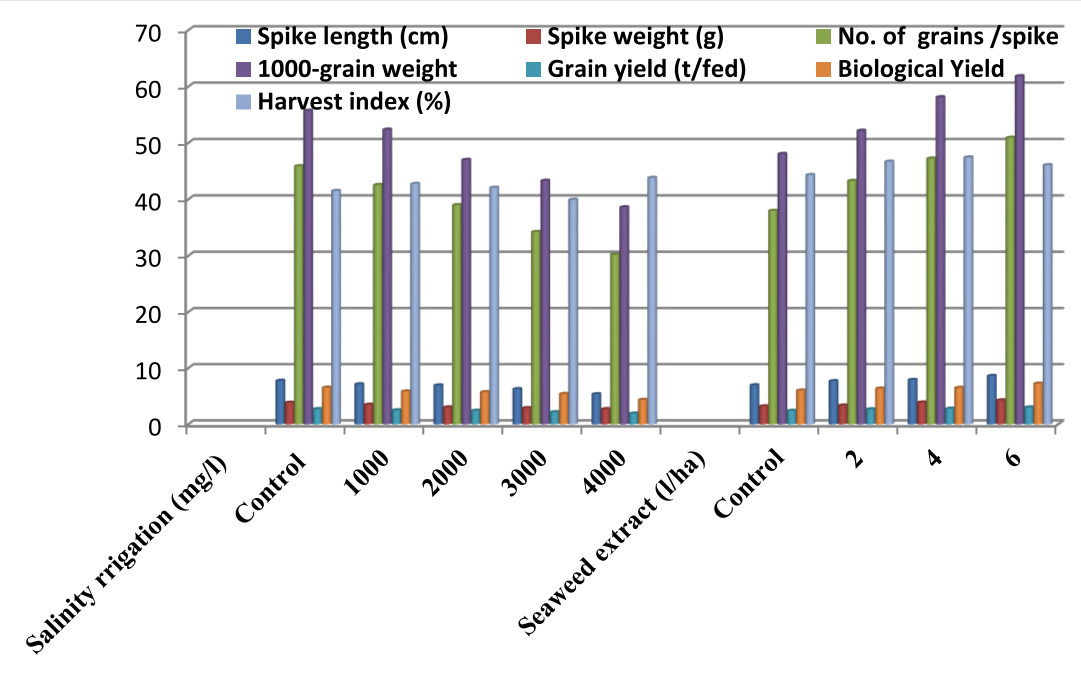

Fig. (2): Effect of salinity irrigation and seaweed extract on yield and yield components of barley c.v. REHAN

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