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The Effect of Liquid Seaweed of Organic Origin on Seed Germination and Seedling Development of Some Winter Cereal Species

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ABSTRACT

In this study, the effects of liquid seaweed on seed germination and seedling growth in some winter cereal species (triticale, barley, and wheat) were investigated. In the study, 6 different doses (D0: tap water D1:1000 ppm L^{-1}, D2:2000 ppm L^{-1}, D3:4000 ppm L^{-1}, D4:8000 ppm L^{-1}, D5:16000 ppm L^{-1}) of seaweed were used. The experiment was conducted according to the split-plot trial design in random plots with 3 replications. Germination rate (%), radicle plumule and seedling length (cm), seedling fresh weight (g), seedling dry weight (g), and seedling vigor index were measured during the 14-day development period of cereal species at all seaweed doses. According to the study findings, except for germination rate in the cereal species; significant differences were found between the mean values of all the properties examined in the cereal types, fertilizer doses, and species x dose interactions. Wheat among cereals had the highest values regarding radicula length, seedling vigor index, seedling dry weight, plumule length, and seedling length. D2 dose from the doses of seaweed fertilizer form; germination rate, seedling vigor index, seedling dry weight, seedling fresh weight, plumule length, and seedling length were found to have the highest values, while D5 dose was the lowest. In terms of species x dose interaction, Germination rate, radicle length, seedling vigor index, and seedling length were found to be high in TxD1 interaction. Germination rate was found to be high in HxD0 interaction. Germination rate, radicle length, seedling vigor index, and seedling dry weight were found to be high in WxD2 interaction. As a result, in the germination study with liquid seaweed, D2 doses for wheat, D1 and D2 doses for triticale, D0, D1, and D2 doses for barley were found as encouraging.

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Organik Kökenli Sıvı Deniz Yosununun Bazı Serin İklim Tahıl Türlerinde Tohum Çimlenmesi ve Fide Gelişimi Üzerine Etkisi

ÖZET

Bu çalışmada sıvı deniz yosununun bazı kışlık tahıl türlerinde tohum çimlenmesi ve fide büyümesi üzerine etkileri araştırılmıştır. Araştırmada 6 farklı dozda (D0: saf su, D1:1000 ppm L^{-1}, D2:2000 ppm L^{-1}, D3:4000 ppm L^{-1}, D4:8000 ppm L^{-1}, D5:16000 ppm L^{-1})deniz yosunu kullanıldı. Deneme tesadüf parsellerinde bölünmüş parseller deneme desenine göre 3 tekerrürlü olarak yürütülmüştür. Tahıl türlerinin 14 günlük gelişim periyodu boyunca tüm deniz yosunu dozlarında çimlenme oranı (%), radikula. plumulu ve fide uzunluğu (cm), fide yaş ağırlığı (g), fide kuru ağırlığı (g) ve vigor indeksi ölçüldü. Araştırma bulgularına göre tahıl türlerinde çimlenme oranı dışında tahıl türleri, gübre dozları ve tür x doz etkileşimlerinde incelenen tüm özelliklerin ortalama değerleri arasında önemli farklılıklar bulunmuştur. Tahıllar arasında buğday, radikula uzunluğu, vigor indeksi, fide kuru ağırlığı, plumula uzunluğu ve fide uzunluğu bakımından en yüksek değerleri elde etmiştir. Deniz yosunu

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gübresinin dozlarından D2 dozu; çimlenme oranı, vigor indeksi, fide kuru ağırlığı, fide yaş ağırlığı, plumula uzunluğu ve fide uzunluğu en yüksek değerlere sahip olurken, D5 dozu en düşük değerlere sahip olmuştur. Türxdoz etkileşimi açısından bakıldığında TxD1 etkileşiminde çimlenme oranı, radikula uzunluğu, vigor indeksi ve fide uzunluğu yüksek bulunmuştur. HxD0 etkileşiminde çimlenme oranı yüksek bulunmuştur. WxD2 etkileşiminde çimlenme oranı, radikula uzunluğu ve vigor indeksi ile fide kuru ağırlığının yüksek olduğu tespit edilmiştir. Sonuç olarak sıvı deniz yosunu ile yapılan çimlendirme çalışmasında buğday için D2 dozları, tritikale için D1 ve D2 dozları, arpa için D0, D1 ve D2 dozları teşvik edici bulunmuştur.

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INTRODUCTION

Winter and spring cereals have an important place in terms of cultivation area and production in the world and Türkiye. Especially in terms of winter cereals, Türkiye has a suitable ecology. Because Türkiye is a part of the Fertile Crescent and the most important gene center of winter cereals. Therefore, the cultivation of barley (*Hordeum* sp.), oat (*Avena* sp.), rye (*Secale* sp.), and triticale (*Triticale*) species, especially bread wheat (*Triticum aestivum* L.) and durum wheat (*Triticum durum* L.), is carried out intensively in Türkiye.

According to TURKSTAT (2022), cereal sufficiency in Türkiye in 2020 was 97.4%. However, sufficiency in wheat was the highest with 102.3%. Among the winter cereals in the same year, the cultivation area of wheat was 5664180 ha for grain and 17866 ha for green grass. Wheat production was 16500000 tons for grain and 348838 tons for green grass. In wheat yield, grain was 2920 kg ha^{-1} and green grass was 19530 kg ha^{-1}. The cultivation area of barley was 2904637 ha in grain and 31319 ha in green grass. In addition, while the production of barley was 7700000 tons in grain and 537066 tons in green grass, the yield was 26500 kg ha^{-1} for grain and 17150 kg ha^{-1} for green grass. The cultivation area of triticale was recorded as 81115 ha for grain and 35009 ha for green grass. Triticale production was 276212 tons for grain and 558643 tons for green grass. In the yield, grain was 3410 kg ha^{-1} and green grass was 15960 kg ha^{-1}.

The issue that can be an alternative to chemical fertilizers or reduce their negative effects is the use of organic fertilizers in agricultural production. Seaweed fertilizer is one of the organic soil conditioners containing humic acid, which positively affects the development of the plant. Organic fertilizers or fertilizer forms provide root development by increasing the oxygen content of the soil and its water-holding capacity and protecting the structure of the soil by reducing salinity in the soil (Kaya & Erdönmez, 2020). This seaweed, a form of organic fertilizer used versatilely in modern agriculture to improve plant growth and increase productivity is a valuable marine resource (Nanda et al., 2021) Seaweed is a form of organic fertilizer that increases germination, helps root development, protects plants against diseases, and pests and prolongs the life of the plant (Hong et al., 1995). For this reason, this study was carried out to determine the effects of seaweed applied in different doses on seed germination and seedling growth in wheat, barley, and triticale, which are winter cereals that have an important place in terms of production and consumption in the world and Türkiye.

MATERIAL and METHOD

The seaweed fertilizer used in the study was produced by Kristal AG Kimya Tarım Sanayi ve Ticaret Ltd. Information about the fertilizer content is given below (Table 1).

Table 1. Seaweed fertilizer's content and amount
Çizelge 1. Deniz yosunu gübresinin içeriği ve miktarı

Seaweed Fertilizer Content	Amount
Organic Matter (%)	15.00
Organic Carbon (%)	10.00
Total Nitrogen (%)	1.00
Water-soluble Potassium Oxide (K_2O) (%)	2.00
Alginic Acid (%)	1.50
Gibberellic Acid (ppm)	0.40
pH	4.00-6.00

This research was carried out in the climate cabinet of Kahramanmaraş Sütçü İmam University Faculty of Agriculture Department of Field Crops Laboratory in April 2021. In the study, triticale (T: Ayşehanım variety). 2-row barley (B: Novosadski variety 565). and

bread wheat (W: Balkoni variety). which are winter cereal species. were used as seeds.

In the research, liquid seaweed fertilizer form was applied in 6 different ways as control (D0: tap water) and 5 doses (D1:1000 ppm L^{-1}. D2:2000 ppm L^{-1}. D3:4000 ppm L^{-1}. D4:8000 ppm L^{-1}. D5:16000 ppm L^{-1}) (Kaya & Erdönmez. 2020). Tap water was used in the preparation of the doses. The experiment was carried out in 3 replications according to the split-plot trial design in random plots. After covering the bottom of 120 mm petri dishes with 2 layers of blotting paper. blotting papers were wetted with 12 ml of prepared solutions. The surface sterilization process was applied to 25 healthy seeds from each cereal type in a 5% NaOCl (sodium hypochlorite) solution for 5 minutes. Afterward, the seeds were washed in tap water and sown in petri dishes to which the solution was added. Petri dishes were covered with parafilm (PM-992) in order to prevent the evaporation of irrigation water at different doses applied and left to germinate for 14 days in an incubator at 20±2 °C. Measurements for germination and seedling development were made on the 15th day.

In the experiment in cereal species, properties such as germination rate (GR) (%), radicle length (RL) (cm), plumule length (PL) (cm), seedling length (PL) (cm), seedling fresh weight (SFW) (g), seedling dry weight (SDW) (g) and seedling vigor index (SVI) were investigated. Images of the research are given below (Figure 1-8).

Figure 1. 6th dose 1st recurrence of triticale
Şekil 1. 6. doz 1. tritikale nüksü

Figure 2. In triticale 1st dose 1st Recurrence
Şekil 1. 6. doz 1. tritikale nüksü

Figure 3. In barley 2th dose 1st recurrence
Şekil 3. Arpada 2. doz 1. nüks

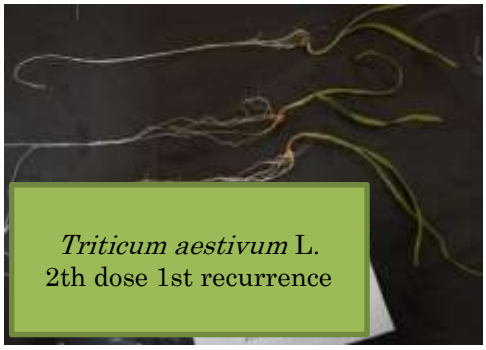

Figure 4. In wheat 2th Dose 1st Recurrence
Şekil 4. Buğdayda 2. doz 1. nüks

Figure 5. In triticale 1st dose 3th Recurrence
Şekil 5. Tritikalede 1. Doz 3. nüks

Figure 6. In triticale 1st dose 1st Recurrence
Şekil 6. Tritikalede 1. Doz 1. nüks

Figure 7. In triticale 1st dose 3th Recurrence
Şekil 7. Tritikalede 1. Doz 3. nüks

Figure 8. In the laboratory. on the 15th day after placing, while seeds are measured for germination and seedling development
Şekil 8. Laboratuvarda. yerleştirmeden sonraki 15. günde; tohumlar çimlenme ve fide gelişimi için ölçülürken

The germination rate of the examined traits was found by counting the germinated seeds and dividing by the total number of seeds. and multiplying by 100. Radicle and plumule lengths were measured separately with the help of a caliper and then the seedling length was calculated by summing the radicle and plumule lengths. The fresh weights of the radicle and plumule length were pondered and the fresh weight of the collected seedlings was found. Then, the dry weight of the seedlings was calculated when they reached a constant temperature in the oven at 70°C. The seedling vigor index was obtained by multiplying the germination rate by the seedling length.

Statistical Analysis of Data

All data obtained from the research were processed by SAS (V. 9.0. 2002) statistical package. All the data were analyzed using analysis of variance (ANOVA) according to the split-plot trial design in random plots. Averages were compared by the Least Significant Difference multiple comparison test (Steel & Torrie, 1980).

RESULTS and DISCUSSION

The average values of the effects of seaweed doses on the seedling growth and germination rate of wheat, barley, and triticale seeds are given in Tables 2,3, 4, and 5.

Germination Rate (%)

According to the variance analysis results obtained, the difference between the doses was statistically very significant ($p<0.001$) in terms of germination rate, the difference between species x dose and species was insignificant (Table 2, Table 3, Table 4).

The germination rate of cereal species varied between 96.00-98.44 % (Table 2). The germination rate of the doses ranged from 92.00% to 100.00%. While the highest germination rate was observed in D0, D1, D2, and D3 (100.00, 100.00, 99.11, and 97.78 %, respectively) doses, the lowest germination rate was found in D4 and D5 doses (Table 3). Within the doses, D4 and D5 seem to have limits on the germination rate. The germination rate of the species x dose interaction varied between 86.67%-100.00%. In the species x dose interaction, the highest germination rate was found in TD0, TD1, TD2, TD4, BD0, BD1, WD0, WD1, and WD2, while the lowest germination rate was found in WD4 (Table 4).

Table 2. Mean values of GR, RL, PL, SL, SWF, SDW, and SVI across species
Çizelge 2. Türler arasında GR, RL, PL, SL, SWF, SDW ve SVI ortalama değerleri.

	Species (S)				
Features	**T**	**B**	**W**	**S average**	**LSD (0.05) S**
GR (%)	98.44	96.00	96.00	96.81	-
RL (cm)	10.95 b	4.92 c	11.95 a	9.27	0.55**
PL (cm)	13.17 b	13.81 a	13.84 a	13.61	0.58*
SL (cm)	24.12 b	18.73 c	25.79 a	22.88	0.89**
SFW (g)	3.58	3.31	3.34	3.41	-
SDW (g)	0.18 b	0.19 b	0.24 a	0.20	0.02**
SVI	2390.17 a	1797.99 b	2492.68 a	2226.95	113.72**

GR: germination rate **RL:** *radicle length* **PL:** plumule length **SL:** seedling length **SFW:** seedling fresh weight **SDW:** seedling dry weight **SVI:** seedling vigor index. **T:** triticale **B:** barley **W:** wheat ***: P<0.05 **:P<0.01.**

Table 3. Mean values of GR, RL, PL, SL, SWF, SDW, and SVI in seaweed doses.
Çizelge 3. Deniz yosunu dozlarında Deniz yosunu dozlarında GR, RL, PL, SL, SWF, SDW ve SVI ortalama değerleri.

Features	Doses (ppm L^{-1})							
	D0	D1	D2	D3	D4	D5	Dose average	LSD (0.05)
GR (%)	100.00 a	100.00 a	99.11 a	97.78 a	92.00 b	92.00 b	96.82	3.39 **
RL (cm)	13.02 a	11.62 b	12.37 ab	8.51 c	6.66 d	3.46 e	9.27	0.79 **
PL (cm)	13.14 b	12.61 bc	14.98 a	13.24 b	15.39 a	12.27 c	13.60	0.82 **
SL (cm)	26.16 a	24.23 b	27.35 a	21.76 c	22.05 c	15.73 d	22.88	1.26 **
SFW (g)	3.64 a	3.54 ab	3.70 a	3.40 b	3.27 b	2.88 c	3.40	0.35 **
SDW (g)	0.21 b	0.18 cd	0.31 a	0.15 d	0.19 bc	0.16 d	0.20	0.02 **
SVI	2616.23 a	2423.22 b	2716.07 a	2134.54 c	2019.95 c	1451.66 d	2226.95	160.82 **

GR: germination rate **RL:** radicle length **PL:** plumule length **SL:** seedling length **SFW:** seedling fresh weight **SDW:** seedling dry weight S**VI:** seedling vigor index. **Fertilizer Doses D0:** Kontrol **D1:** 1000 ppm L^{-1} **D2:** 2000 ppm L^{-1} **D3:** 4000 ppm L^{-1} **D4:** 8000 ppm L^{-1} **D5:** 16000 ppm L^{-1}**. The same letters in each line are in the same group.** In multiple comparison test; **:P<0.01.

Table 4. Mean GR. RL. PL. SL. SFW. SDW and SVI values in seaweed doses of species.
Çizelge 4. Ortalama GR. RL. PL. SL. SFW. Türlerin deniz yosunu dozlarında SDW ve SVI değerleri.

Species (S)	Doses (ppm L^{-1})	GR (%)	RL (cm)	PL (cm)	SL (cm)
T	D0	100.00 ± 0.00	14.36 ± 0.65 bc	13.63 ± 0.10 c-f	27.99 ± 0.67 bcd
	D1	100.00 ± 0.00	17.11 ± 0.80 a	15.23 ± 0.63 a-e	32.34 ± 1.41 a
	D2	100.00 ± 0.00	15.18 ± 0.47 ab	14.42 ± 0.28 b-e	29.60 ± 0.66 abc
	D3	98.67 ± 1.33	9.09 ± 0.46 d	12.90 ± 0.29 e-h	21.99 ± 0.44 e
	D4	100.00 ± 0.00	6.48 ± 0.21 ef	13.31 ± 0.62 d-g	19.79 ± 0.61 e
	D5	92.00 ± 2.31	3.48 ± 0.24 gh	9.53 ± 0.51 j	13.01 ± 0.60 f
B	D0	100.00 ± 0.00	8.29 ± 0.09 de	13.88 ± 0.53 cde	22.17 ± 0.61 e
	D1	100.00 ± 0.00	3.94 ± 0.15 g	11.10 ± 0.63 hij	15.04 ± 0.75 f
	D2	97.33 ± 1.33	4.95 ± 0.33 fg	16.35 ± 0.49 ab	21.31 ± 0.37 e
	D3	96.00 ± 2.31	3.83 ± 0.26 gh	10.39 ± 0.48 ij	14.22 ± 0.58 f
	D4	89.33 ± 5.81	3.90 ± 0.15 g	10.70 ± 0.46 abc	19.60 ± 0.61 e
	D5	93.33 ± 3.53	4.60 ± 0.32 fg	15.43 ± 0.82 a-d	20.04 ± 1.03 e
W	D0	100.00 ± 0.00	16.40 ± 0.47 a	11.92 ± 0.60 f-i	28.33 ± 1.06 bc
	D1	100.00 ± 0.00	13.82 ± 0.88 bc	11.49 ± 0.43 g-j	25.31 ± 0.07 d
	D2	100.00 ± 0.00	16.97 ± 0.85 a	14.17 ± 0.49 cde	31.15 ± 1.12 ab
	D3	98.67 ± 1.33	12.62 ± 0.80 c	16.44 ± 0.51 ab	29.06 ± 1.25 bc
	D4	86.67 ± 2.67	9.61 ± 0.54 d	17.15 ± 0.70 a	26.77 ± 1.16 cd
	D5	90.67 ± 1.33	2.29 ± 0.1 h	11.85 ± 0.43 f-i	14.14 ± 0.41 f
Overall Average		96.81	9.27	13.33	22.88
LSD (0.05) S x D		-	2.41**	2.49**	3.96**
CV (%)		3.63	8.83	6.30	5.74

T: triticale. **B:** barley. **W:** wheat. **GR:** germination rate **RL:** radicle length **PL:** plumule length **SL:** seedling length **CV:** coefficient of variation **T:** species. **D:** dose**. Fertilizer Doses; D0:** control. **D1:** 1000 ppm L^{-1} **D2:** 2000 ppm L^{-1} **D3:** 4000 ppm L^{-1}. **D4:** 8000 ppm L^{-1}. **D5:** 16000 ppm L^{-1}. There is no statistical difference between the same capital letters in the same column. There is no statistical difference between the same lowercase letters in the same column. In multiple comparison test; *: P<0.05 **:P<0.01.

In their previous studies on seaweed, Kaya & Erdönmez (2020) in their research to determine the effect of 6 different doses (D0: control, D1:1000 ppm L^{-1}, D2:2000 ppm L^{-1}, D3:4000 ppm L^{-1}, D4:8000 ppm L^{-1}, D5:16000 ppm L^{-1}) of seaweed on soybean germination and seedling development; they found the highest germination rate at 84.00% to D2 dose and the lowest germination rate at 20.00% to D5 fertilizer dose. In the study, it was detected that the germination rate decreased with the increase of the seaweed fertilizer dose, except for the control application, and this is consistent with our findings. Demirkaya (2016), in her study, examined the effect of germination rate in pepper seeds on the osmotic conditioning of seaweed extract applied at different times and doses with Methyl Jasmonate at different times. As a result of the data obtained, it was observed that the germination rate of pepper seeds would increase with seaweed extract at both 20 °C and 15 °C, the application period

of which was 1 day. Möller and Smith (1999) investigated the water sensitivity of seaweed suspensions from *Ascophyllum nodosum* (Linnaeus) Le Jolis (ANS) and *Laminaria hyperborea* (Gunn.) *Foslie* (LHS) in barley seeds in their study. As a result of the research, they reported that both seaweeds did not reduce the viability of barley seed but increased germination. Zodape (2001) reported in her study that the application of seaweed material before planting increased the germination rate of many vegetable seeds. As can be understood from the studies, it is seen that the germination rate varies depending on the type of plant used, variety, and seed size. Hong et al. (2007) found in their study that 20% of brown seaweed increased the seed germination percentage and produced a lower germination rate of 100%. Altuner et al. (2019) found in their study that the highest germination rate in the application of salt stress (0, 50, 100, and 200 mM) and gibberellic acid (0,100,200 and 300 ppm) to triticale seeds was 70.2% in the application of 300 ppm gibberellic acid in 0 mM salt stress.

Radicle Length (cm)

According to the results of the analysis of variance, it was determined that the statistical difference between the cereal types, doses, and species x dose interaction ($p<0.001$) in terms of radicle length was very important (Table 2, Table 3, Table 4). The radicle length of the cereal species was found to be between 4.92 cm and 11.95 cm. While the highest radicle length was observed in W among cereal species, the shortest radicle length was found in B (Table 2). The radicle length of the doses was observed between 3.46 cm and 13.02 cm. While the longest radicle length was observed in the D0 dose, the shortest radicle length was found in the D5 dose. Among the doses, the D5 dose seems to have a limiting effect on the radicle length (Table 3). The radicle length of the species x dose interaction ranged from 2.29 cm to 17.11 cm. Within the species x dose interaction, the highest radicle length was found in TD1, WD2, and WD0 (17.11, 16.97, and 16.40 cm, respectively). and the shortest radicle length was found in WD5 (Table 4). In their previous studies on seaweed. Kaya & Erdönmez (2020) found the highest radicle length at 10.01 cm at a dose of D2, and the shortest radicle length at a fertilizer dose of 3.58 cm at D5. In the study, it was observed that the radicle length decreased with the increase of the seaweed fertilizer dose, except for the control application. and their findings support our findings. Bat et al. (2019) investigated the effects of seaweed doses (0 (control), 2, 4, and 6 cc L^{-1}) applied in viols on echinacea plants under drought stress. As a result of the study, the highest radicle length was obtained in the seaweed extract application at 16.17 cm, and the shortest radicle length in the 6 cc L^{-1} application was obtained in the control application at 13.28cm. Mrogan & Tarjan. (1980) reported that seaweed material applied to tomato plants increased root growth in their study. Finnie & Staden (1985). in their study. found that the extract obtained from the seaweed material of *Ecklonia maxima* (sea bamboo) increased rooting in tomato plants. Kara et al. (2019) investigated the effect of seaweed applications (control (0), 2, 4, and 6 cc L^{-1}) on salt stress (control, NaCl, KCl, and $CaCl_2$) in the echinacea plant. As a result of the research, they reported that the highest average radicle length was obtained with 14.8 cm at the dose of 6 cc L^{-1} seaweed, and the lowest average radicle length was obtained at 13.4 cm in the control application. As can be understood from the studies, the difference in seed size in different plant species and cultivars affects the root length. Güngör et al. (2017), in their study investigating the effect of different doses of salt concentration (0, 50, 100 mM) on the radicula length of the oat plant, observed that the highest radicle length was 6.87 cm at 0 mM salt concentration.

Plumule Length (cm)

In the analysis of variance, the difference between doses and species x dose interaction in terms of plumule length was found to be statistically significant ($p<0.001$) while the difference between cereal species was significant ($p=0.042$) (Table 2, Table 3, Table 4). The plumule length of the cereal species was stated to be between 13.17-13.84 cm. While the highest plumule length was observed in W and B (13.84 and 13.81 cm. respectively) among cereal species, the shortest plumule length was detected in the T type (Table 2). The plumule length of the doses was observed between 12.27-15.39 cm. Among the doses, the longest plumule length was observed in D4 and D2 (15.39 and 14.98 cm, respectively) and the shortest plumule length was observed in D5 (12.27 cm) (Table 3). The plumule length of the species x dose interaction was determined between 9.53-17.15 cm. In the species x dose interaction, the highest plumule length was observed in WD4, and the shortest plumule length was observed in TD5. In their previous studies on seaweed (Table 4). Kaya & Erdönmez (2020) found the highest plumule length at 10.01 cm at a dose of D2, and the lowest plumule length at 3.58 cm at a fertilizer dose of D5. In the study, it was observed that the plumule length decreased with the increase of the seaweed fertilizer dose, except for the control application, and their findings support our findings. Bat et al. (2019) in their research; they determined that the highest plumule length was obtained in the application of 6 cc L^{-1} seaweed extract at 21.42 cm, and the shortest plumule length was obtained at 18.21 cm in the control application. Kara et al. (2019) observed that the highest average plumule length was obtained with 18.00 cm at the dose of 2 cc L^{-1} seaweed, and the lowest

average plumule length was obtained at 15.40 cm in the control application.

Seedling Length (cm)

According to the results of the analysis, the statistical difference between cereal types, doses, and species x dose interaction in terms of seedling length was found to be very significant ($p<0.001$) (Tables 2, 3, and 4). The seedling length of the cereal species was found to be between 18.73-25.79 cm. Among the cereal species, the longest seedling length was determined in W type, and the shortest seedling length was determined in B type (Table 2). The seedling length of the doses was found to be between 15.73-27.35 cm. While the longest seedling length was observed at D2 and D0 (27.35 and 26.16 cm, respectively) doses, the shortest seedling length was observed at D5 dose. D2 seems to be more stimulating in terms of seedling length (Table 3). It has been determined that the species x dose interaction varies between 13.01-32.34 cm in seedling length. Within the species x dose interaction, the highest seedling length was observed in TD1, and the shortest seedling length was observed in TD5, BD3, WD5, and BD1 (13.01, 14.22, 14.14 and 15.04 cm, respectively) (Table 4). Allwright (1992) observed in a study that seaweed material increased plant height in wheat.

Seedling Fresh Weight (g)

In the analysis of variance, the difference between the doses and the species x dose interaction in terms of seedling fresh weight was found to be statistically very significant ($p<0.001$), but it was found to be unimportant in terms of species (Table 2, Table 3 and Table 5). The seedling fresh weight of the cereal species varied between 3.31-3.58 g (Table 2). The seedling fresh weight of the doses varied between 2.88-3.70 g. The highest seedling fresh weight was obtained at D2 and D0 (3.70 and 3.64 g. respectively) doses, and the lowest seedling fresh weight was obtained at D5 doses (Table 3). The seedling fresh weight of the species x dose interaction ranged from 2.28 g to 4.06 g. Within the species x dose interaction, the highest seedling fresh weight was observed in TD2, and the lowest seedling fresh weight was observed in WD5 (Table 5). Kaya & Erdönmez (2020) found the highest seedling fresh weight at 1041.00 mg and D1 dose, and the lowest seedling fresh weight at 621.666 mg and D5 fertilizer dose. Their findings agree with our findings. Kaya & Coşkun (2020) in their research determined the effect of 6 different doses (D0: control (tap water). D1: 1000 ppm L^{-1}. D2: 2000 ppm L^{-1}. D3: 4000 ppm L^{-1}. D4: 8000 ppm L^{-1} and D5:16000 ppm L^{-1}) of seaweed on rapeseed germination and seedling development; they determined that the highest seedling fresh weight was 79.23 mg with D2, the lowest seedling fresh weight was 46.60 mg with D1, and germination did not occur at D5.

Seedling Dry Weight (g)

In the analysis of variance, the difference between cereal types, doses, and species x dose interaction in terms of seedling dry weight was found to be statistically very significant ($p<0.001$) (Table 2, Table 3, and Table 5). The seedling dry weight of the cereal species varied between 0.18-0.24 g. Among the species, the highest seedling dry weight was detected in the W type, and the lowest seedling dry weight was detected in the T and B types (0.18 and 0.19 g respectively) (Table 2). The seedling dry weight of the doses varied between 0.15-0.31 g. Among the doses, the highest seedling dry weight was obtained at the D2 dose, and the lowest seedling dry weight was obtained at the D3 and D4 doses (0.15 and 0.16 g, respectively) (Table 3). The seedling dry weight of the species x dose interaction ranged from 0.12 g to 0.48 g. Within the species x dose interaction, the highest seedling dry weight was observed in WD2, and the lowest seedling dry weight was observed in TD3, TD5, and BD3 (Table 5). Allwright (1992) stated that seaweed material increased plant height and plant dry weight in wheat. Kaya & Erdönmez (2020) in their research; they detected the highest seedling dry weight was detected at the dose of 155.667 mg and D2, and the lowest seedling dry weight was detected at the fertilizer dose of 96.833 mg and D5 doses. Their findings agree with our findings. Kaya & Coşkun (2020) found that the highest seedling dry weight was 8.716 mg with D2, the lowest seedling dry weight was 5.126 mg at D1, and germination did not occur at D5.

Seedling Vigor Index

In the analysis of variance, the statistical difference between cereal types, doses, and species x dose interaction was found to be very significant ($p<0.001$) in terms of seedling vigor index weight (Table 2, Table 3, and Table 5). The seedling vigor index of cereal species varied between 1797.99 and 2492.68. The highest seedling vigor index among the cereal types was found in W and T (2492.68 and 2390.17, respectively) types, and the lowest seedling vigor index was found in the B type (Table 2). The seedling vigor index of the doses ranged from 1451.66 to 2716.07. Among the doses, the highest seedling vigor index was determined at the D2 and D0 doses (2716.07 and 2616.23, respectively), and the lowest seedling vigor index was found at the D5 dose (Table 3). The seedling vigor index of the species x dose interaction was observed to vary between 1198.98 and 3233.90. Among the species dose interaction, the highest seedling vigor index was in TD1, WD2, TD2, WD3, and WD0 (3233.90, 3114.83, 2959.99, 2870.63, and 2832.58, respectively). while the lowest seedling vigor index in TD5, WD5, and BD3 (1198.98, 1281.54, and 1363.11, respectively), was observed (Table 5). Kaya & Erdönmez (2020) found the highest seedling vigor

index in 1991.09 at 1000 ppm L^{-1} dose. and the lowest seedling vigor index at 236.58 at D5 fertilizer dose. Kaya & Coşkun (2020) they found that the highest seedling vigor index was 14848.52 in the D0 application. the lowest seedling vigor index was 354.74 at the dose of D2. and the germination did not occur at the dose of D5.

Table 5. Mean SFW. SDW and SVI values in seaweed doses of species
Çizelge 5. Ortalama SFW. Türlerin deniz yosunu dozlarında SDW ve SVI değerleri

Species (S)	Doses (ppm L^{-1})	SFW (g)	SDW (g)	SVI
T	**D0**	3.36 ± 0.18 bcd	0.20 ± 0.00 cde	2798.99 ± 67.3 ab
	D1	4.01 ± 0.15 ab	0.20 ± 0.01 cde	3233.90 ± 141 a
	D2	4.06 ± 0.07 a	0.23 ± 0.01 bc	2959.99 ± 66.4 a
	D3	3.85 ± 0.19 ab	0.12 ± 0.01 g	2169.89 ± 59.9 c-f
	D4	3.50 ± 0.05 abc	0.19 ± 0.01 def	1979.25 ± 60.9 def
	D5	2.67 ± 0.10 ef	0.12 ± 0.01 g	1198.98 ± 80.3 h
B	**D0**	3.76 ± 0.21 ab	0.24 ± 0.01 b	2217.12 ± 61.2 cde
	D1	3.21 ± 0.07 cde	0.16 ± 0.01 ef	1504.52 ± 75.3 gh
	D2	3.68 ± 0.11 abc	0.21 ± 0.01 cd	2073.40 ± 37.3 def
	D3	2.85 ± 0.04 de	0.12 ± 0.00 g	1363.11 ± 36.7 h
	D4	3.38 ± 0.74 bc	0.17 ± 0.05 cd	1755.36 ± 157 fg
	D5	3.68 ± 0.15 abc	0.21 ± 0.01 cd	1874.45 ± 152 ef
W	**D0**	3.80 ± 0.23 ab	0.19 ± 0.01 de	2832.58 ± 106 a
	D1	3.41 ± 0.16 bc	0.18 ± 0.01 ef	2531.24 ± 107 bc
	D2	3.37 ± 0.12 bc	0.48 ± 0.01 a	3114.83 ± 112 a
	D3	3.51 ± 0.04 abc	0.22 ± 0.01 bcd	2870.63 ± 161 a
	D4	3.67 ± 0.19 abc	0.21 ± 0.01 bcd	2325.25 ± 166 cd
	D5	2.28 ± 0.07 f	0.15 ± 0.00 f	1281.54 ± 26.4 h
Overall Average		3.45	0.20	2226.95
LSD (0.05) S x D		0.68**	0.04**	501.83**
CV (%)		10.66	12.99	7.50

T: triticale **B:** barley **W:** wheat **SFW**: seedling fresh weight **SDW**: seedling dry weight **SVI**: seedling vigor index **CV:** coefficient of variation **T:** species **D:** dose. **Fertilizer Doses; D0:** Control **D1:** 1000 ppm L^{-1}. **D2:** 2000 ppm L^{-1} **D3:** 4000 ppm L^{-1} **D4:** 8000 ppm L^{-1} **D5:** 16000 ppm L^{-1}. There is no statistical difference between the same capital letters in the same column. There is no statistical difference between the same lowercase letters in the same column. In multiple comparison test; *: P<0.05 **:P<0.01.

CONCLUSION

Many studies on seaweed organic material are mostly done on vegetable species, but not many studies have been done on cereal species. In addition, it is seen that there is not much research on seaweed material in germination studies. With this study, the effect of seaweed organic material on the germination of cereal species will be determined and will guide many future studies. In the study, it was observed that the data on the germination and seedling development of the cereal species of seaweed doses were statistically significant, D2 (2000 ppm L^{-1}) dose from the 6 different seaweed doses used in the experiment; the highest values in terms of germination rate, seedling vigor index, seedling dry weight, seedling fresh weight, plumule length and seedling length, D5 (16000 ppm L^{-1}) dose gave the lowest values. Among the cereal types, wheat; radicle length, seedling vigor index, seedling dry weight, plumule length, and seedling length reached the highest values among other species. In species x dose interaction, T x D1 (Triticale x 1000 ppm L^{-1}) in terms of germination rate, radicle length, seedling vigor index, and seedling length; In terms of BD0 (barley x control) germination rate; WD2 (wheat x 2000 ppm L^{-1}) was at the forefront in terms of germination rate, radicle length, seedling vigor index, and seedling dry weight.

As a result, while D2 (2000 ppm L^{-1}) dose of seaweed organic material is generally recommended for wheat from cereal species, D1 (1000 ppm L^{-1}) and D2 (2000 ppm L^{-1}) doses in triticale, D0 (control) among other species, D1 (1000 ppm L^{-1}) and D2 (2000 ppm L^{-1}) doses are recommended as incentives in barley.

Contribution Rate Statement Summary of Researchers

The experiment was planned by A.R. Kaya. The

experiment was planned by A.R. Kaya. All authors also carried out the statistical analysis. wrote the first draft of the paper. and had it accepted.

Conflict of Interest

The authors declare that he/she has no conflict of interest.

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