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EFFECTS OF SEAWEED APPLICATIONS ON PHENOLOGICAL DEVELOPMENT STAGES AND TOTAL EFFECTIVE TEMPERATURE IN YUVARLAK ÇEKIRDEKSIZ GRAPE VARIETY GROWN IN SIIRT CONDITIONS

Tuba UZUN BAYRAKTAR[1]*, Gülcan AYGÜL[2], Cüneyt UYAK[3]

[1]*Siirt University, Faculty of Agriculture, Department of Horticulture, 56200, Siirt, Türkiye*
[2]*Siirt University, The Graduate School of Natural and Applied Sciences, Department of Horticulture, 56200, Siirt, Türkiye*
[3]*Van Yüzüncü Yıl University, Faculty of Agriculture, Department of Horticulture, 65080, Van, Türkiye*

Abstract: This study was carried out on the Yuvarlak Çekirdeksiz grape variety cultivated in Siirt University Implementation and Research Vineyard. Four different doses of liquid seaweed extract was applied at three different periods (control -0 ppm; 1st application period (before flowering) - 1000 ppm; 2nd application period (before flowering + after flowering)-1000 ppm + 1000 ppm = 2000 ppm; and 3rd application (before flowering + after flowering + veraison) -1000ppm + 1000 ppm + 1000 ppm = 3000 ppm). The effects of seaweed application on phenological stages and Total Effective temperature (TET) of Yuvarlak Çekirdeksiz grape variety were compared. When the plants with seaweed applications at different phenological periods were compared with the control, it was observed that plants with the first application period had a full flowering phase three days earlier and the veraison phase six days earlier. The Total Effective Temperature value between full bloom and veraison was determined to be between 659.78-819.98 day-degrees (dd), and it was determined that applying seaweed before flowering shortened the vegetation period compared to the control. In contrast, the other two applications extended the vegetation period.

Keywords: Seaweed, Phenological observations, Vegetation period

***Corresponding author:** Siirt University, Faculty of Agriculture, Department of Horticulture, 56200, Siirt, Türkiye
E mail: tubauzun@siirt.edu.tr (T. UZUN BAYRAKTAR)
Tuba UZUN BAYRAKTAR https://orcid.org/0000-0003-2625-0684
Gülcan AYGÜL https://orcid.org/0000-0002-5911-0672
Cüneyt UYAK https://orcid.org/0000-0002-6101-6845

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1. Introduction

Vine is one of the species whose cultivation was given at least as much importance as barley and wheat in ancient civilizations and has an important place in plant production today. North East Anatolia, the Caucasus, and the Georgian basin, which are considered to be the regions where the first viticulture began, are the areas where viticulture has been actively maintained until today (Anonymous, 2021). Viticulture activities generally occur between 20-40° latitude in the southern hemisphere and 20-52° latitude in the northern hemisphere (Koç, 2020). Although the history of viticulture and winemaking is as old as the history of humanity, it has an important place in economic terms today. Grapes are one of the most commonly cultivated plants grown in the world because the propagation method is easy, it is not very selective in terms of soil and climate requirements, and it can be used in different ways.

The Southeastern Anatolia Region is one of the oldest viticulture centers in the world. In this region, the Siirt region also has a deep-rooted viticulture culture (Uyak et al., 2011). Although there are fertile vineyard areas in Siirt, vine development has gradually decreased, and quality grape vines cannot be obtained because pruning practices currently done to increase the amount of product are wrong (Akın and Kısmalı, 2004). Farm manure and chemical fertilizers are used indiscriminately in the region, and as a result of the continuous use of these fertilizers, there is a decrease in micronutrients and consequently a decrease in product quality. To further exacerbate this problem, foliar fertilizer (seaweed) is currently not utilized by the farmers (Haliloğlu et al., 2005).

In order to reduce micro and macronutrient deficiency caused by various environmental stress factors, foliar fertilization applications are increasing. Although foliar fertilization does not completely replace soil fertilization, especially in crops with large leaf areas, it can increase nutrient uptake and yield. In addition, it is estimated that increasing biotic and abiotic stress factors on plants will have more negative effects on crops in the 21st century, which will reduce yields (IPCC, 2007). For this reason, developing ecological and sustainable methods to mitigate the effects of such stressors has become one of our priorities. Recently, many products have been tested in sustainable agricultural practices to support plant growth. Seaweed extracts, one of the most commonly tested substances, are shown as an organic farm input in sustainable agriculture because they are ecologically safe and harmless. *Ascophyllum nodosum* L. is the seaweed most commonly used as biostimulants or biofertilizers to increase plant growth and productivity.

Seaweed and products derived from seaweed are widely used as yield stimulants in plants due to the presence of micronutrients such as molybdenum, cobalt, manganese, boron, zinc, copper, iron, macronutrients such as potassium and calcium, as well as multiple growth regulators such as cytokinins, auxins, and gibberellins (Koç, 2020).

In parallel with the recent developments in the field of nanotechnology, many fertilizer companies have started to offer their products integrated with this technology to the market. However, the frequency and dose of these fertilizers should be supported by scientific studies. This study was carried out to determine the effects of different doses of seaweed extract (ALGİNARİN_X) applications on the phenological development stages and the Total Effective Temperature of Yuvarlak Çekirdeksiz grape variety grown within 2021-2022 in the Siirt University Implementation and Research vineyard.

2. Materials and Methods

2.1. Materials

2.1.1. Features of the trial vineyard

This study was carried out on the Yuvarlak Çekirdeksiz grape variety grafted on 1103 Paulsen rootstocks grown in the production vineyard of the Viticulture Implementation and Research Center at Kezer Campus of Siirt University. The vineyard was established in 2014 with a pergola trellising system in such a way that the row spacing is 3 m and the row is 1.5 m. The coordinates of the vineyard in which the experiment was conducted are 37º 58' 9.6" N latitude, 41º 50' 46.4" E longitude, and 583m altitude (Figure 1).

2.1.2. General characteristics of plant material

The Yuvarlak Çekirdeksiz grape variety is a productive variety with seedless grains, and very strong and semi-erect vines. Its origin is the Aegean Region of Türkiye. The fruit is small and oval in shape. The shell is thin and light yellow in color, and the inside of the grain is crispy, fleshy, and juicy. It can be generally used as dried fruit and sometimes as table wine. It is suitable for long or mixed pruning (Kısmalı, 1978; Fidan, 1985). Since it is seedless, its grains are small and can grain (Figure 2). The grain can be enlarged by girdling and applying hormones.

2.1.3. Properties of seaweed

Seaweed is a simple aquatic plant that lives in oceans, seas and fresh waters. It can have a red, green or brown appearance. Red and brown algae usually live in the seas. Seaweeds are species that contain almost all primary and secondary nutrients, trace elements and have proven effects in agriculture. Some of the most important substances in the content of seaweed are; alginic acid, vitamins, auxins, at least two types of gibberellin and antibiotics. These substances can be found in fresh seaweed, dried seaweed flour, and liquid seaweed extract. Of these substances, alginic acid is a soil conditioner; others can be considered as plant regulators. By spraying leaves with seaweed extracts, a more suitable nutrient medium is created for the bacteria on the leaf surface that contribute significantly to the photosynthesis process, and an increase in the photosynthesis rate is observed. The efficiency of photosynthesis is further increased by the penetration of substances such as auxins and gibberellins through the leaf. In addition, in this way, the mobility of mineral substances in the leaves increases and possible blockages in the leaf pores are eliminated (Anonymous, 2022).

Figure 1. Satellite image of the trial vineyard (Google Earth, 2020).

Berry Properties
Color: Green-yellow
Shape: Sphere
Size: Small
Core State: Seedless
Shell thickness: Thin
Aroma: Sweet
Features of cluster
Shape: Elongated Cylindrical
Frequency: Frequent
Largeness: Coarse
Flower structure: Self-fertile
Cultural Features
Ripening time: Mid-season (early August)
Pruning request: Long
Region: Aegean Region
Direction of use: Fresh, drying

Figure 2. Image and characteristics of the Yuvarlak Çekirdeksiz grape variety (Uzun, 2020).

2.2. Methods

The study was carried out in the vineyard within Siirt University in the vegetation year of 2021. Annual maintenance operations such as pruning, tillage, fertilizer, and pesticide applications were carried out regularly.

In this study, in the form of foliar spraying on the vines of the Yuvarlak Çekirdeksiz grape variety, "ALGİNARİN-X (content: total organic matter = 15%; organic carbon = 6.5%; total nitrogen = 1.5%; potassium oxide = 1.5%; and pH = 8-10)" was applied at three different growth periods and doses. The application periods are: before flowering, after flowering, and veraison.

Form of trial;

Control → 0 ppm

1. Application (Before flowering) → 1000 ppm
2. Application (Before flowering + After flowering) → 1000 ppm+1000 ppm=2000 ppm
3. Application (Before flowering + After flowering + Veraison) → 1000 ppm+1000 ppm+1000 ppm=3000 ppm

In the experiment, 4 applications [Control, 1. Application, 2. Application and 3. Application] x 3 repetitions x 5 vines in each repetition = 60 vines.

2.3. Data Received and Analyses

2.3.1. Soil analysis

Soil analysis was carried out in the laboratory of Siirt University Science and Technology Application and Research Center Directorate.

Soil samples for analysis were taken from a depth of 30-60 cm. Physical properties and macro and micronutrient contents of soils were evaluated according to Aksu (2008).

2.3.2. Climate data

The climate data (temperature, humidity, amount of lighting) of the trial vineyard (from budburst to leaf fall) where the study was carried out were determined by the data obtained from the HOBO U12-013 Onset brand device attached to the tie wire of the vine arms (1 record in 60 minutes). In addition, the data obtained were used in the calculation of the Total Effective Temperature (TET). The amount of solar irradiance was recorded with the W/m2 unit with the Apogee brand pyranometer device connected to the HOBO device, and the data obtained (1 record in 60 minutes) were turned into monthly averages, and the relationship of the applications with the climate parameters was also examined.

Climate data for the trial vineyard were obtained in the vegetation year 2021. Monthly average temperature, minimum temperature, maximum temperature, average humidity, minimum humidity, maximum humidity, average amount of lighting, minimum amount of lighting, and maximum amount of lighting were calculated from the time of budburst to the date of leaf fall.

2.3.3. Total effective temperature and lighting amounts according to phenological stages

With the data obtained from the HOBO and pyranometer device placed in the trial vineyard where the study was carried out, the total effective temperature and lighting amounts at different stages of each application were determined for budburst to full flowering; full flowering to veraison; veraison to harvest; budburst to veraison; full flowering to harvest; and budburst to harvest periods in each dose application. Total Effective Temperature (TET) (day-degrees) values were calculated, and the amount of radiation for these periods was also calculated.

3. Results and Discussion

3.1. Soil Analysis Results

The trial vineyard has a moderately alkaline soil structure with clayey (C) texture, no salt, very calcareous, with very little organic matter (Table 1). If we look at the concentration of macro and micronutrients; K and Fe are sufficient; Ca and Mn are high; Mg, Zn and Cu are intermediate; B less; P is at a very low level (Table 2).

Although viticulture is carried out in soils with many different structures, loamy (L) or sandy-loam (SL), slightly gravelly, well-aerated, humus and moderate calcareous soils are ideal vineyard soils, and it is reported that the most suitable pH for vineyards is between 6-8 (Yetgin and Korkmaz, 1991; Celik et al., 1998; Celik, 2011).

Table 1. Determination of soil structure of the trial vineyard

Structure	Value
Clay (C) (%)	56.3
Sil (S) (%)	30.7
Sand (S) (%)	13
Texture Grade	C
Ph	8.02
Salt (Ds/M)	0.17
Organic Matter (%)	0.92
Lime (%)	17.74

Table 2. Determination of macro and micronutrient elements of the trial vineyard

Element	Value
Cu (ppm)	0.73
Mn (ppm)	7.22
Fe (ppm)	8.51
Zn (ppm)	0.73
B (ppm)	0.4
K_2O (kg/da)	86.06
P_2O_5 (kg/da)	2.5
Ca (mg/kg)	1882.87
Mg (mg/kg)	347.56

As stated in Table 3, the budburst of the vines in the Yuvarlak Çekirdeksiz grape variety was on 26.03.2021; Leaf fall took place on 22.11.2021 and the monthly average temperature, humidity and lighting amount values were calculated by taking into account these dates. The monthly average high temperature was 32.66 °C in July, while the monthly average low temperature was 8.54 °C in March. The minimum temperature was -1.21 °C in March, while the maximum temperature was 46.48 °C in July. The highest monthly average humidity was in November with 71.40%, while the lowest monthly average humidity was in August with 25.05%. The minimum humidity was 5.86% in June and the maximum humidity was 100.00% in November. In determining the average monthly illumination and the minimum illumination, nighttime was excluded from the assessment due to the absence of natural lighting during those hours. While the highest monthly average irradiation was in March with 327.93W/m^2, the lowest monthly average irradiation was in October with 63.19W/m^2. While the minimum amount of irradiation was measured as 3.05W/m^2 in other months except March, the maximum amount of irradiation was measured in April with 1001.20W/m^2. Since the maximum amount of lighting was taken into account, the amount of lighting tended to decrease with the acceleration of vegetative development, beginning with the vines' awakening on March 26, 2021. However, due to the decrease in leaf area caused by the removal of unproductive clusterless shoots, that is, shoots sprouting from secondary buds in the same winter bud, on 20.04.2021, a gradual increase in the maximum amount of irradiation was observed. In addition, it is estimated that this increase made within the scope of summer pruning on 2.07.2021 caused the vines to transition to generative growth and further increased the maximum amount of irradiation. The maximum amount of irradiation decreased with the decrease in the length of the day after the equinox in September, and the maximum amount of irradiation increased again with leaf fall in November.

3.2. Phenological Observations of Applications

Phenological observations from 2021, when the study was conducted, are given below. Phenological observations were determined by taking into account the classification made by Eichorn and Lorenz (1977) (Table 4).

Table 3. Monthly temperature, humidity and lighting amount values of the trial vineyard in 2021

Months	Temperature (°C)			Humidity (%)			Radiation Amount (W/m^2)***		
	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
March (26-31.03.2021)*	8.54	-1.21	24.56	70.36	18.12	96.87	327.93	9.15	927.95
April	17.24	2.74	33.50	54.52	10.21	99.11	285.21	3.05	1001.20
May	24.16	8.89	40.29	37.19	9.68	97.27	106.71	3.05	894.40
June	28.29	12.82	44.38	25.55	5.86	57.42	92.53	3.05	924.90
July	32.66	18.53	46.48	25.05	7.74	53.58	78.70	3.05	149.55
August	30.80	17.56	43.89	26.95	8.18	67.50	77.48	3.05	384.60
September	24.49	9.04	40.14	33.52	8.58	97.03	122.51	3.05	827.25
October	18.27	4.43	35.66	42.56	8.97	98.35	63.19	3.05	271.65
November (01-22.11.2021)**	12.21	0.33	26.67	71.40	25.83	100.00	117.80	3.05	680.70

*Since the budburst date is 23.03.2021, registration has started from this date, **Since the leaf fall date is 22.11.2021, the registrations have been terminated on this date, ***While calculating the average amount of lighting per month and the minimum amount of lighting, they are not included in the calculation because there is no lighting at night.

Table 4. Phenological observations according to seaweed applications

Phenological Observations	Control	1. Application*	2. Application**	3. Application***
Budburst	26.03.2021	26.03.2021	26.03.2021	26.03.2021
Beginning of Flowering	05.05.2021	03.05.2021	03.05.2021	03.05.2021
Full Flowering	09.05.2021	06.05.2021	06.05.2021	06.05.2021
End of Flowering	12.05.2021	09.05.2021	09.05.2021	09.05.2021
Berry Set	17.05.2021	13.05.2021	13.05.2021	13.05.2021
Veraison	23.06.2021	17.06.2021	25.06.2021	25.06.2021
Harvest****	05.08.2021	05.08.2021	05.08.2021	05.08.2021
Leaf Fall	22.11.2021	26.12.2021	28.12.2021	29.11.2021

*1. Application; It was carried out once before flowering (on 28.04.2021), **2. Application; It was carried out twice, before flowering (on 28.04.2021) and after flowering (on 25.05.2021), ***3. Application; It was carried out three times: before flowering (on 28.04.2021), after flowering (on 25.05.2021) and after veraison period (on 02.07.2021), ***The harvest was done on the same day in order to be able to compare the effects of the applications.

Table 5. Total effective temperature (TET) values for phenological periods according to applications

Periods	Control	1. Application*	2. Application**	3. Application***
Budburst-Full flowering (dd)	316.74	280.31	280.31	280.31
Full flowering-Veraison (dd)	744.28	659.78	819.98	819.98
Veraison-Harvest (dd)	984.85	1102.81	946.17	946.17
Budburst-Veraison (dd)	1048.22	927.72	1087.92	1087.92
Full flowering-Harvest (dd)	1709.82	1745.82	1745.82	1745.82
Budburst-Harvest (dd) ****	2013.76	2013.76	2013.76	2013.76

*1. Application; It was carried out once before flowering (on 28.04.2021), **2. Application; It was carried out twice, before flowering (on 28.04.2021) and after flowering (on 25.05.2021), ***3. Application; It was carried out three times: before flowering (on 28.04.2021), after flowering (on 25.05.2021) and after veraison period (on 02.07.2021), ****Since the harvest was done on the same day to be able to compare the effects of the applications, the TET value between budburst-harvest date was the same in all treatments.

In the vegetation year of 2021, when the research was conducted, the budburst of the vines took place in the last week of March. While the full flowering phase takes place in the second week of May in the control application, it has been determined that the first seaweed application before flowering (28.04.2021) in other applications brings the vegetation period forward by three days and takes place in the first week of May. While veraison phase takes place in the last week of June in the control application, 1. In practice, it was observed that after the second seaweed application in the third week of June and after flowering (25.05.2021) in the other two applications, it was delayed by two days according to the control and eight days compared to the first application and in the last week of June (Table 4).

3.3. Total Effective Temperature (TET) according to Phenological Periods

One of the most important parameters taken into account in deciding the suitability of a region for viticulture or which varieties can be grown in that ecology is the effective temperature sum value. This value is expressed as day-degrees (dd).

Total Effective Temperature (TET) (dd) values between budburst to full flowering, full flowering to veraison, veraison to harvest, budburst to veraison, full flowering to harvest and budburst to harvest dates were calculated for control and each seaweed application.

According to the seaweed applications of the 2021 vegetation year, the TET values calculated based on six different phenological periods of the Yuvarlak Çekirdeksiz grape variety are given in Table 5.

In 2021, the TET values calculated in the period from budburst to harvest were determined as 2013.76 dd in all applications. As can be seen in Table 5, it was determined that the first seaweed application before flowering decreased (659.78 dd) and the other two seaweed applications increased (819.98 dd) the TET value between full flowering-veraison compared to the control. It has been concluded that the reason for this is that the macro and micronutrients contained in seaweed encourage this growth in the period up to the flowering phase when vegetative growth accelerates, but they lose their effect with the acceleration of generative growth after flowering (Table 5).

The lower limit of the total effective temperature suitable for viticulture in an ecology is considered to be 900 dd (Eggeberger et al., 1975). Their ecologies according to TET values;

Cold= 900-1 400 dd
Cool =1 401-1 700 dd
Temperate= 1 701-1 950 dd
Warm-temperate= 1 951-2 250 dd
Hot= 2 251 dd and above
(Winkler et al., 1974).

Considering that the TET value for hot-temperate climate class plants should be between 1951-2250 dd (Winkler et al., 1974), it was determined that the ecology in which the study was carried out was in the warm-temperate climate class.

3.4. Amount of Irradiation according to Phenological Periods (W/m²)

In addition to affecting the physiological events of plants, light is also effective on the morphological shape of the organs, the formation of flower organs and flowering. The increase in light intensity causes the acceleration of feathering, stunting and the formation of color pigments such as anthocyanins in plants. Daylight is one of the most important climatic factors affecting viticulture. Duration and degree of sunbathing has a decisive effect on many properties of grapes, such as color, aroma, acidity, sugar and ripening. Plants need a certain amount of light in order to carry out maximum photosynthesis. Light is the most important factor affecting net assimilation, as it provides all the energy necessary for photosynthesis. In order for plants to use their chemical bond energy in the production of organic matter (photosynthesis), they must be cut off by the crown part of the plant and the ability to convert this interrupted light energy into chemical energy (light use efficiency) must be high (Hay and Walker, 1989).

The average amount of radiation (W/m²) between budburst to anthesis, anthesis to veraison, veraison to harvest, budburst to veraison, anthesis to harvest, and budburst to harvest dates was calculated for control and each seaweed application. When calculating the average amount of lighting, night hours were excluded in the calculation because there was no radiation at night.

According to the seaweed applications of the 2021 vegetation year, the amount of radiation calculated based on six different phenological periods of the Yuvarlak Çekirdeksiz grape variety is given in Table 6.

In 2021, the values of the amount of radiation calculated in the period from budburst to harvest were determined as 143.24 W/m² in all treatments. As shown in Table 6, it was determined that the first seaweed application before flowering decreased the amount of radiation between anthesis to veraison (94.93 W/m²), and the other two seaweed applications increased it (95.66 W/m²) according to the control. It has been concluded that the reason for this is that it stimulates growth due to the biological stimulants, nutrients and carbohydrates contained in seaweed in the period until the flowering phase when vegetative growth accelerates, but it loses this effect with the acceleration of generative growth after flowering (Table 6).

For the ripening of grapes, effective sunshine duration is as important as the degree of temperature (Oraman, 1970). Each grape variety requires a certain amount of sunlight to ripen and attain standard variety characteristics. The degree and duration of sunlight in each vineyard varies depending on the location and direction of the vineyard (Fidan and Eriş, 1975). It is reported that for economical viticulture, this value should not be less than 1500-1600 hours (Çelik et al., 1998).

Table 6. Average radiation amounts of phenological periods according to applications

Periods	Control	1. Application*	2. Application**	3. Application***
Budburst-Anthesis(W/m²)	258.18	270.79	270.79	270.79
Anthesis-Veraison (W/m²)	94.90	94.93	95.66	95.66
Veraison-Harvest (W/m²)	81.13	82.47	79.35	79.35
Budburst-Veraison (W/m²)	174.32	180.51	172.97	172.97
Anthesis-Harvest (W/m²)	88.08	88.22	88.22	88.22
Budburst-Harvest (W/m²)****	143.24	143.24	143.24	143.24

When calculating the average amount of lighting, night hours were not included in the calculation because there was no irradiation at night, *1. Application; It was carried out once before flowering (on 28.04.2021), **2. Application; It was carried out twice, before flowering (on 28.04.2021) and after flowering (on 25.05.2021), ***3. Application; It was carried out three times: before flowering (on 28.04.2021), after flowering (on 25.05.2021) and after veraison period (on 02.07.2021), ****Since the harvest was done on the same day to be able to compare the effects of the applications, the TET value between budburst-harvest dates was the same in all treatments.

4. Conclusion

In the 2021 vegetation year when the research was conducted, it was determined that a dose of seaweed applied to the Yuvarlak Çekirdeksiz grape variety before flowering shortened the vegetation period, while other seaweed applications extended the vegetation period. Considering these results, it was concluded that applying one dose of seaweed for early grape cultivation and two doses for late grape cultivation would be sufficient.

Author Contributions

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	T.U.B.	G.A.	C.U.
C	50	30	20
D	80	10	10
S	90	10	
DCP	60	30	10
DAI	80	10	10
L	50	40	10
W	80	10	10
CR	50	25	25
SR	100		
PM	85	10	5
FA	80	10	10

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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