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Stimulatory Effects of Different Seed Priming Treatments on Germination and Early Seedling Growth of Sugar Beet

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Abstract

As known, seed germination constitutes the first stage in plant production, and the rapidness of this trait is important for the agriculture of the sugar beet. Particularly, it is crucial to realize after the winter and cool weather. The main aim of the study was to accelerate seedling growth by germinating them observe their effects on plant emergence, and improve seed viability using Serenada, Aranka, and Lider sugar beet varieties treated with hydropriming, hormonal priming, and organic priming for 6, 12, and 18 h under room temperature and humidity conditions. The study showed that the behavior of treated seeds was significantly different compared to the control treatment. The germination percentage, mean germination time, shoot length and root length ranged between 85.50-95.00 (%), 2.80-4.49 (days), 6.34-9.82 (cm), and 3.73-9.12 (cm) respectively. Seedling fresh and dry weight changed between 57.88-89.66 (mg plant^{-1}), and 5.02-12.31 (mg plant^{-1}) in the same order. The best results in germination percentage, mean germination time, root length, and maximum seedling dry weight were obtained after seaweed treatments for 18 h, for seedling length seedling fresh weight. It is concluded that growth parameters are genotype-dependent. Used genotypes in this experiment showed different responses for the investigated agronomic characters (with the priming treatments), and they can be used in any local sugar beet programs for the investigated traits with a carefully selected depending on the objectives of the study.

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1. Introduction

Sugar beet (*Beta vulgaris* L.) crop plants have always been of strategic importance to Türkiye (Topak et al., 2010) since this plant is used in wide sectors (candy industries, biscuits, waffle, etc.) in agriculture as sugar powder, hybrid, and monogerm seeds. On the other hand, germination ability and emergence percentage/homogeneity of the seeds are very important factors in its production. Similarly, cultivation is rather important since the germination of sugar beet grown in drought and semi-drought-hit areas tends to be irregular and can span over a long period.

Generally speaking, the germination period of a seed is the most important stage for the cultivation of that plant (Turan and Samur, 2024), which constitutes the first stage in crop production and prevents optimum germination and emergence depending on factors such as environmental factors (soil moisture, temperature, soil salinity, etc.) and seed structure (seed maturity, hard-shelled species, genetic structure, etc.) (Bareke, 2018). Germination is the most important stage of seedling formation plays and an important role in plant production. As known, priming is beginning to play an important role among new technologies in seed development (Chomontowski et al., 2020). The main agronomic purpose of this application is to accelerate germination, and plant emergence to improve seed viability and accelerate seedling growth. Under appropriate temperature and humidity conditions, many methods, such as hydropriming, halopriming, osmopriming, hormopriming, soil matrix priming, and biopriming, are mainly used to examine the effects of seed treatments on germination (Rhaman et al., 2020). Primed seed gives earlier, more uniform, and sometimes greater seedling, establishment, and growth (Mondal and Bose, 2021).

Liquid seaweed extracts improve nutrient and water uptake by favorably affecting the root development of plants (Dutta et al., 2019; Ali et al., 2021). They also increase the plant canopy by accelerating the formation of chlorophyll; therefore, liquid seaweed extracts provide more protein, carbohydrates, and other substances, making plants resistant to diseases and pests, and environmental stresses such as extreme heat, frost, insufficient sunlight, drought, and excessive cold (Chaturvedi et al., 2022). They are a source of macro and micronutrients for plants and can increase yield by up to >30.0 %. Liquid seaweed extracts enhance resistance against viruses and reduce nematode damage. They increase the effectiveness of pesticides by about 25.0 %, improve quality, and increase the market and export value of products (Blunden et al., 1992). With seaweed extract, it has been determined that the plant shows resistance against stress factors; with robust root development seedling growth and development (Matsiyak et al., 2011). There is increasing interest in the use of biostimulants such as seaweed extracts as a crop cultivation technique to influence vegetative growth and increase fruit yield without adversely affecting plant quality (Hernández-Herrera et al., 2023). The beneficial effects of seaweed extracts can be attributed to chemical compounds such as minerals, amino acids, vitamins, and phytohormones that enrich soils and are therefore widely used in agriculture to achieve their desired potential (Yakhin et al., 2017). Seaweed (*Ascophyllum nodosum*) extract, is one of the organic preparations, known to increase plant growth by promoting germination in seeds (Güneri, 2023). In many previous studies, it has been determined that seaweeds have positive effects on early seedling stage (Ağırağaç and Zorer Çelebi, 2022).

Another priming agent is kinetin, and it is one of the leading plant growth regulators (Othman et al., 2021), and affects cell differentiation by initiating the activation of enzymes necessary for vital reactions, leading to increased cell division, cell elongation, and growth, and increasing RNA activation (Wu et al., 2021; Sharma et al., 2022). Additionally, the effectiveness of this technology in increasing and harmonizing the percentage of germination and field emergence, improving seedling strength and growth characteristics, and thus increasing crop yield (Bindraban et al., 2015; Jaiswal et al., 2022; Sundareswaran et al., 2023). Kinetin hormone plays an important role in plant growth and development (Hamayun et al., 2015). Research on the effects of this hormone on seed germination reveals different results in various plant species (Mensah et al., 2020). Generally, it has been observed that kinetin promotes seed germination and accelerates the germination process. The effects of kinetin on seed germination are also related to its regulation of the division and growth processes of plant cells (Soliman, 2019). Seeds are stimulated by soaking with natural or synthetic compounds to increase their ability to withstand various stress factors, to promote germination strength with uniformity. Therefore, the current study aimed to compare the germination behaviors of sugar beet seeds after hydropriming, hormonal priming (kinetin), and organic priming (seaweed) for different durations of time.

2. Materials and Methods

2.1. Materials

Pure monogerm seeds of three sugar beet varieties Serenada, Aranka, and Lider were used in the experiment, and they were obtained from Ankara Sugar Mills (Private) Ltd. Etimesgut, Türkiye

2.2. Methods

The seeds were treated for 6, 12, and 18 h before starting the experiment, the seeds of all varieties were soaked in 5 % sodium hypochlorite solution for sterilization with distilled water (3 × 5 minutes) each and dried to their initial weight.

- Control treatment (The seeds of each variety were used without any treatment)
- Hydropriming (distilled water),
- Seaweed (5 g l^{-1}) was preferred for organic application.

The commercial name **L OCEAN** solid seaweed was used as a seaweed liquid source.

- Kinetin (0.25 mg l^{-1}) was preferred as a hormonal treatment.

Seeds primed with kinetin and seaweed were rinsed three times with distilled water for 5 min to remove traces of the respective chemicals from the surface of the seeds and then dried to their initial weight. This research was replicated four times with 50 seeds in each replicate to assess the viability level of a total number of 200 seeds for each parameter. The counted number of seeds in each treatment was placed on a three-layered filter paper moistened with 20 mL of pure water. The rolled papers were packed in sealed plastic bags and incubated at 24 ± 1 °C in an incubator in the dark to prevent moisture loss and promote seed germination. The seeds with a radicle length of 2 mm were counted as germinated (Day and Kocak-Sahin, 2023).

The mean germination percentage is calculated by formula (Formula 1). Mean germination time was noted every 24 h following (Anonymous, 2017) with the help of formula (Formula 2). Where (n) is the number of total seeds germinated in 24 h and (D) is the number of days counting from the start of the germination experiment.

$$GP = \frac{Germinated\ seeds\ at\ final\ day}{Total\ seeds} \times 100 \quad (1)$$

$$MGT = \sum(\mathrm{Dn})/\sum \mathrm{n} \quad (2)$$

At the end of 14 days, shoot length, root length, and seedling fresh weight were measured taking twenty seedlings randomly taken from each replicate (Day et al., 2024; Kulan et al., 2021). The dry weight was recorded after the samples were obtained in an oven at 72 °C for a period of 48 hours (Day et al., 2024).

2.3. Statistical analysis of data

The experimental results have been tested by analysis of variance, using a Completely Randomized Design one factorial experiment with four replications using the JMP-12 statistical program (Anonymous, 2015) to compare the differences among treatment means using Duncan's multiple range test (DMRT).

3. Results and Discussion

Seed germination is the most significant and vital stage in crop production. Losses in crop production are experienced due to low seed-quality germination and stress. Primed seeds of each variety showed variable effects on germination percentage, mean germination time, shoot length, root length, seedling fresh weight, and seedling dry weight compared to the control treatment.

3.1. Germination percentage

Germination percentage showed a statistically significantly different germination percentage of cultivars after different priming treatments ($p \leq 0.01$). Priming treatments with each variety were divided into three groups. The performance of each variety in every group was compared with the control treatment. Minimum seed germination was noted in control treatments, where varieties Serenada, Aranka, and Lider indicated germination percentages of 85.50 %, 87.00 %, and 86.00 %. The highest germination percentage was obtained from seaweed (18 h) treatment in cv. Serenada (95.00 %) and cv. Lider (93.50 %). A minimum germination percentage was noted after hydropriming (18 h) treatment in cv. Aranka (92.50 %). They had a positive effect on GP in all treatments with an increase in the time of priming. Variety Serenada, Aranka, and Lider had germination percentages of 90.00-92.00 %, 91.50-92.50 %, and 90.50-92.00 % after hydropriming. The Germination percentage of these three varieties improved from 91.50-95.00 %, 91.00-92.00 %, and 92.00-93.50 % after treatment with seaweed extract. Cv. Serenada, Aranka, and Lider had Germination percentage of 89.00-91.00 %, 88.00-92.00 %, and 91.50-93.00 % after Kinetin treatment (Table 1).

Table 1. Effects of differential priming on germination percentage (%) in sugar beet varieties

Priming Treatment	Duration (h)	Varieties		
		Serenada	Aranka	Lider
Control	0	85.50^{c**}	87.00^{b**}	86.00^{b**}
Hydropriming	6	90.00^{b}	91.50^{ab}	90.50^{a}
	12	91.00^{ab}	92.00^{ab}	91.50^{a}
	18	92.00^{ab}	92.50^{a}	92.00^{a}
Priming with Seaweed extract	6	91.50^{ab}	91.00^{ab}	92.00^{a}
	12	92.50^{ab}	91.50^{ab}	93.00^{a}
	18	95.00^{a}	92.00^{ab}	93.50^{a}
Priming with Kinetin	6	89.00^{bc}	88.00^{ab}	91.50^{a}
	12	89.00^{bc}	90.00^{ab}	92.00^{a}
	18	91.00^{ab}	92.00^{ab}	93.00^{a}

**All values shown by small letters in a column are significantly different using Duncan's multiple range test at $p<0.01$ level of significance

3.2. Mean germination time

A significant interaction was noted among the mean germination time (day) of different cultivars after different priming treatments ($p \leq 0.01$). Regardless of the three cultivars and the duration of their treatments, each variety took the longest time to germinate the seeds under control treatment. The maximum mean germination time was found for cv. Serenada (4.34 days), cv. Aranka (4.49 days) and cv. Lider (4.36 days). The minimum mean germination time was obtained from kinetin (18 h) treatment in cv. Serenada (3.35 d) while it was obtained from seaweed (18 h) treatment in cv. Aranka (2.80 days) followed by cv. Lider (2.85 days).

Mean germination time reduced priming at different times when compared with the control treatment. Hydropriming treatments reduced seed germination duration from 3.76-3.80 days, 3.27-3.49 days, 3.47- 3.79 days in cv. Serenada, Aranka, and Lider respectively (Table 2).

Priming for different durations with seaweed extracts also reduced the germination time. It ranged from 3.84-3.56 days, 3.35-2.80 days, 3.82- 2.85 days in cv. Serenada, Aranka, and Lider respectively. A partial reduction in germination duration was noted after kinetin treatment, it varied between 3.93-3.35 days, 4.00-3.22 days, and 3.90- 3.48 days in cv. Serenada, Aranka, and Lider respectively. The fastest germination time was noted on all three varieties after 18 h treatment (Table 2).

Table 2. Effects of differential priming on mean germination time (day) in sugar beet varieties

Priming Treatment	Duration (h)	Varieties		
		Serenada	Aranka	Lider
Control	**0**	4.34^{a**}	4.49^{a**}	4.36^{a**}
Hydropriming	**6**	3.80^{bc}	3.49^{bc}	3.79^{ab}
	12	3.78^{bc}	3.36^{cd}	3.60$^{a\text{-}c}$
	18	3.76^{bc}	3.27^{cd}	3.47^{bc}
Priming with Seaweed extract	**6**	3.84$^{a\text{-}c}$	3.35^{cd}	3.82^{ab}
	12	3.60^{bc}	3.36^{cd}	3.28^{bc}
	18	3.56^{bc}	2.80^{d}	2.85^{c}
Priming with Kinetin	**6**	3.93^{ab}	4.00^{ab}	3.90^{ab}
	12	3.47^{bc}	3.49^{bc}	3.68$^{a\text{-}c}$
	18	3.35^{c}	3.22^{cd}	3.48$^{a\text{-}c}$

**All values shown by small letters in a column are significantly different using Duncan's multiple range test at p<0.01 level of significance

3.3. Shoot length

A statistically significant interaction was noted after each priming treatment when compared with the control treatment ($p \leq 0.01$) for each variety. The maximum shoot length was obtained from the seaweed treatment (18 h) with 9.56 cm in cv. Serenada, while the lowest shoot length was obtained from the control treatment with 6.34 cm. In the Aranka variety, the maximum shoot length was obtained from hydropriming (18 h) treatment at 9.82 cm and the lowest shoot length was obtained from control treatment at 7.30 cm. In the Lider variety, the highest shoot length was obtained from seaweed extract (18 h) and hydropriming treatment (18 h) at 9.23 cm, and the minimum shoot length was obtained from the control treatment with a length of 6.53 cm. (Table 3).

Table 3. Effects of differential priming on shoot length (cm) in sugar beet varieties

Priming Treatment	Duration (h)	Cultivars		
		Serenada	Aranka	Lider
Control	**0**	6.34^{d**}	7.37^{bc**}	6.53^{d}
	6	7.98^{bc}	7.69^{bc}	7.18^{cd**}
Hydropriming	**12**	9.05$^{a\text{-}c}$	9.61^{a}	8.85^{ab}
	18	9.56^{a}	9.82^{a}	9.23^{a}
Priming with Seaweed extract	**6**	8.03^{bc}	7.76^{cb}	6.73^{d}
	12	9.30^{ab}	8.80$^{a\text{-}c}$	8.60$^{a\text{-}c}$
	18	9.40^{ab}	9.06^{ab}	9.23^{a}
Priming with Kinetin	**6**	7.76^{cd}	7.30^{c}	7.55$^{b\text{-}d}$
	12	8.19$^{a\text{-}c}$	8.51^{abc}	9.11^{ab}
	18	8.42$^{a\text{-}c}$	8.57$^{a\text{-}c}$	9.21^{a}

**All values shown by small letters in a column are significantly different using Duncan's multiple range test at p<0.01 level of significance

3.4. Root length

A statistically significant interaction was noted for root length ($p \leq 0.01$). Minimum root length was noted using seeds without any pretreatment (control treatment), regardless of the sugarbeet varieties. The maximum root length was obtained from the seaweed treatment at 8.26 cm in the Serenada, while the lowest root length was obtained from the control treatment at 3.72 cm. In the Aranka, the maximum root length was obtained from hydro treatment with a root length of 8.70 cm, and the minimum root length of 5.09 cm was obtained from the control treatment. The Lider showed a maximum root length of 9.12 cm.

Table 4. Effects of differential priming on root length (cm) in different sugar beet varieties

Priming Treatment	Duration (h)	Cultivars		
		Serenada	Aranka	Lider
Control	**0**	3.72^{d**}	5.09^{e**}	4.15^{g**}
Hydropriming	**6**	5.55^{c}	7.55^{bc}	6.70^{c-e}
	12	6.04^{bc}	7.87^{a-c}	7.61^{bc}
	18	6.62^{b}	8.70^{a}	7.99^{b}
Priming with Seaweed extract	**6**	8.06^{a}	7.04^{cd}	6.60^{c-e}
	12	8.08^{a}	7.66^{a-c}	7.29^{b-d}
	18	8.26^{a}	8.37^{ab}	9.12^{a}
Priming with Kinetin	**6**	5.06^{c}	5.30^{e}	5.47^{f}
	12	5.07^{c}	6.16^{de}	6.02^{ef}
	18	5.14^{c}	7.70 $^{a-c}$	6.34^{d-f}

**All values shown by small letters in a column are significantly different using Duncan's multiple range test at p<0.01 level of significance

3.5. Seedling fresh and dry weights

Seedling fresh and dry weight (mg plant^{-1}) of sugar beet varieties used in the study showed statistically significant interaction among three different varieties and priming treatments ($p \leq 0.01$). Seedling fresh weight (mg Plant^{-1}) ranged from 86.66 and 57.88 mg plant^{-1}, and seedling dry weight (mg plant^{-1}) ranged from 12.31 - 5.02 mg plant^{-1} (Figures 1-2). Among the treatments, seedling fresh weight increased by 12 and 18 h duration of hydropriming, seaweed, and kinetin treatments compared to hydration, seaweed, and kinetin treatments ($p \leq 0.01$). However, the maximum dry weight of 11.59 mg plant^{-1} among the treatments was obtained within the seaweed (18 h) treatment, and the minimum value was obtained with 5.83 mg plant^{-1} in the control treatment ($p \leq 0.01$) (Figures 1-2).

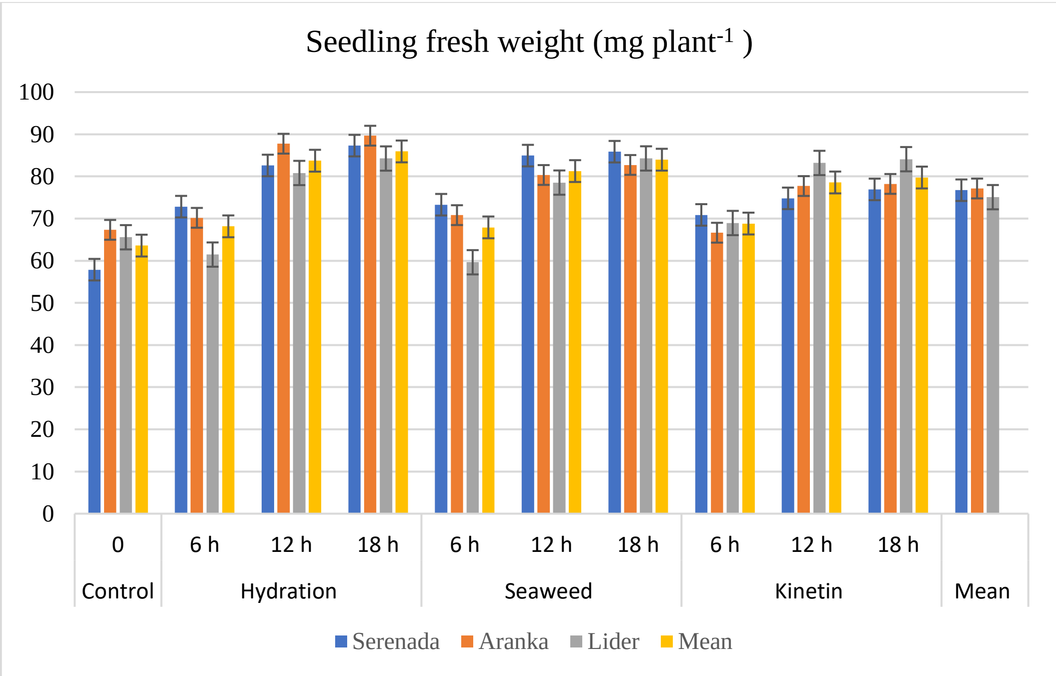

Figure 1. Effects of differential priming on seedling fresh weight (mg plant^{-1}) in different sugar beet varieties

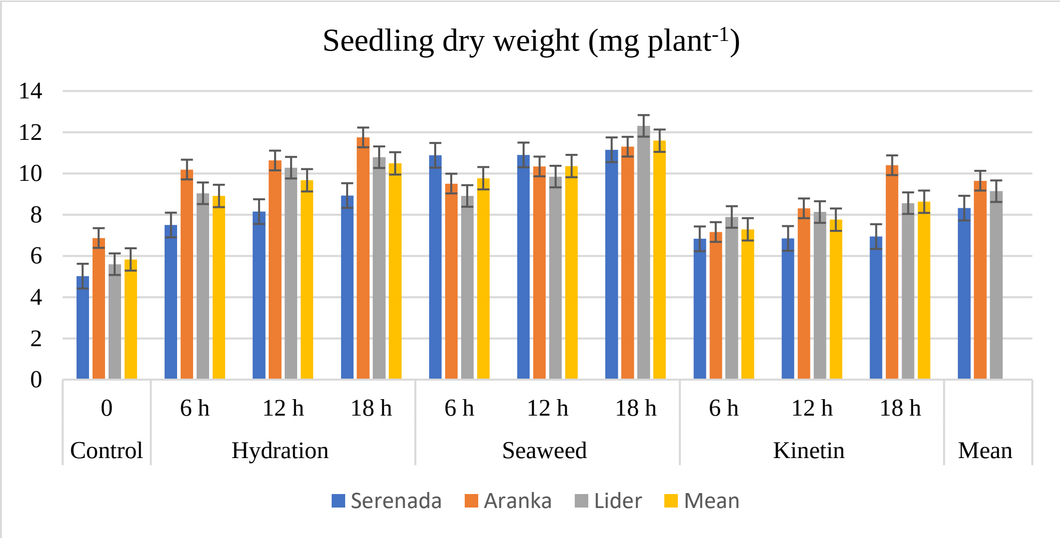

Figure 2. Effects of differential priming on seedling dry weight (mg plant^{-1}) in different sugar beet varieties

The results of the present study showed that the prepared seeds (hydropriming, seaweed, and kinetin) exhibited improved parameters used in the study. Priming treatments showed faster and shorter germination than the control treatments. This had a positive effect on seedling length and root growth. It was noted that priming increased seedling height and root growth compared to the control treatments. Higher fresh and dry seedling weights were also obtained from all primed seeds compared to the control. The major advantage of seed treatment was attributed to faster seed germination, seedling growth and faster emergence, which gave more time for seedlings to develop (Mutlu-Durak and Yildiz Kutman, 2021). Seed priming has been shown to increase germination and seedling quality for many crops (Sağlam et al., 2010; Guo et al. 2022). Researchers have reported that priming has a beneficial effect on different plant seeds, such as sugar beet (Chomontowski et al., 2020), rice (*Oryza sativa*) (Afzal et al., 2021), soybean (*Glycine max*) (Miljaković et al., 2022), and triticale (Guo et al., 2022).

Germination begins when a dry seed absorbs water and is completed when part of the seed emerges from the surrounding structure, known as the emergence phase (Lara-Viveros et al., 2020). Previous studies demonstrated that corn (*Zea mays* L.) seed hydropriming for 12 and 18 h showed an agronomic advantage for mature plants (Lara-Viveros et al., 2020). Sung and Chiu (1995) claimed that emergence vigor and seedling growth were increased by hydropriming in watermelon (*Citrullus lanatus* (Thunb.)). The findings we obtained from hydropriming are similar. This can be related to faster water uptake and earlier onset of metabolic processes in the hydroprimed seeds compared to the control, resulting in a shorter germination time. (Day, 2022).

Nedumaran (2017), has reported that seeds treated with seaweed germinate faster due to the high mineral content of ocean water and its ability to absorb water at maximum level. The stimulant effect of seaweed (SW) priming may be due to the content of enzymes, phytohormones, minerals, and low molecular weight compounds in the extracts (Stirk and Van Staden, 2020). Thriunavukkarasu et al. (2020) reported that different concentrations of seaweed in red pepper (*Capsicum annuum* L.) seeds increased germination by 8 %. Another researcher emphasized the positive effect of seaweed application on germination and other yield elements in bean plants (*Phaseolus vulgaris* L.) (Abou El-Yazied et al., 2012). They reported that seaweed extract applications significantly increased the germination rate compared to the control application (Demirkaya and Arslan, 2021). The impact of seaweed application on germination and seedling strength of corn seeds was found to be positive (Matysiak et al., 2011).

Application of the plant growth hormone kinetin is known to be effective in improving both germination and growth of various crop species (Ansari et al., 2020). Kinetins have been shown to increase germination percentage and seedling growth, as they were found to play a controlling role in integrating responses expressed by plants, which could be explained by faster water uptake in primed seeds, as germination in primed seeds started after one day (Abeed et al., 2021; Sharma et al., 2022). Barley seeds treated with 60 mg l^{-1} kinetin gave the highest germination percentage and root length values, while 120 mg l^{-1} concentration gave the highest germination vigor and shoot length values (Mohammed, 2023). In another study, it was reported that kinetin had a positive effect on emergence percentage, mean germination time, seedling length, and seedling fresh weight in sugar beet seed treatments compared to the control (Kaya and Kulan, 2020). Similar results were obtained for tomato by Zeb et al. (2018), wheat by Jaiswal et al. (2022), rice by Kareem et al. (2023), and papaya by Rani et al. (2024).

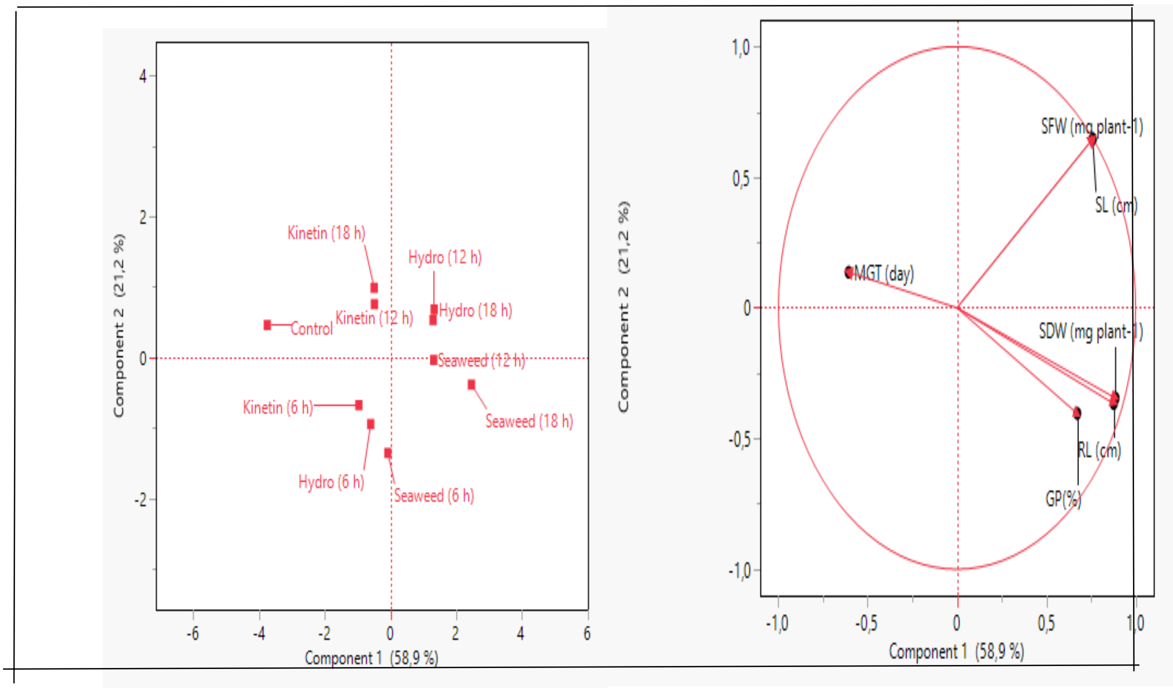

Figure 3. Principal components 1 and 2 were obtained from germination and seedling growth data in sugar beet varieties (GP= germination percentage, MGT=mean germination time, SL= shoot length, RL =root length, SFW= seedling fresh weight and SDW =seedling dry weight)

The gradient of impact on the growth correlation groups for each different time and priming agent used in this study is depicted in a two-dimensional representation known as a principal component analyzing (PCA) (Figure 3). The model including the principal components accounted for 80.1 % of the total variance explained by the different priming treatments applied (58.9 % for PC1 and 21.2 % for PC2). The first principal component (PC1) explained 58.9 % of the variance and was positively correlated with SL (cm), GP (%), RL (cm), and SFW and SDW while they were negatively correlated with mean germination time (day) (Figure 3). The second principal component (PC2) was positively correlated with MGT (day), SL (cm) and SFW, and was negatively correlated with GP (%), RL (cm), and SDW (mg plant^{-1}), and accounted for 21.2 % of the total variance of the data (Figure 3). By visualizing the data obtained, it was observed that the germination and seedling growth parameters differentiated SL (cm) from other parameters when applying different priming treatments (Figure 3).

4. Conclusions

Sugar beet holds strategic importance for Türkiye, and needs seed priming treatments for uniform seed germination. Three varieties (Serenada, Aranka and Lider) were used in this study to determine the effect of different seed treatments on germination. Seed priming treatments for several durations of time indicated an improvement in germination parameters compared to the control among the varieties. The best germination response was obtained from the Aranka variety, using seaweed and hydropriming extract treatments for 18 h. It is concluded that growth parameters are genotype-dependent. Therefore, the genotypes should be carefully selected depending on the objectives.

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