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Article

Effects of Salicylic Acid Priming Application in Some Switchgrass (*Panicum virgatum* L.) Cultivars

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Abstract: This study aimed to determine the effects of salicylic acid (SA) seed priming applications on the germination parameters of switchgrass (*Panicum virgatum* L.). The research was carried out in Siirt University, Faculty of Agriculture, Field Crops Laboratory, under controlled conditions at 25±1 °C. The subject of the study consists of the SA priming doses which is (0, 0.10, 0.25, 0.50, 0.75, 1.00 and 1.25 mM) applied to 3 different cultivars of switchgrass (*P. virgatum* L.) (Kanlow, Shawnee and Trailblazer). The experiment was carried out in Petri dishes according to the randomized complete design with four replications. In the study, germination parameters such as germination percentage, mean germination time, germination index and coefficient of uniformity of germination, and seedling growth parameters such as seedling fresh and dry weight, seedling vigor index were examined. It was detected that all parameters except for seedling fresh weight were statiscally differences among the cultivars ($p<0.01$). In addition, SA doses significantly affected all germination and seedling growth parameters except seedling fresh weight. To sum up, pre-sowing seed priming with SA can be effective in breaking the seed dormancy and 0.25 mM SA can be used to improve germination and seedling growth in switchgrass to overcome dormancy problem.

Key words: Switchgrass, Cultivars, Salicylic Acid, Germination, Seedling Growth

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1. Introduction

The seed pre-application technique (seed priming) is based on drying the seeds again by keeping them in water or a solution with low osmotic potential for a certain period of time and under certain temperature conditions before planting (Sher et al., 2019; Abbasi Khalaki et al., 2021); In recent years, it has been used effectively in the agricultural field in germination and seedling development, in regulating some metabolic and physiological processes in plants, and in improving biotic and abiotic stress tolerance. In this technique, which aims to treat seeds with various agents that activate the physiological processes of seeds (Abbasi Khalaki et al., 2021), some endogenous growth regulators such as abscisic acid, jasmonic acid and salicylic acid (SA) have recently been used.

Salicylic acid, a natural phenolic compound and a phytohormone (Farooq et al., 2008; Singh and Gautam, 2013; Souri and Tohidloo, 2019), has been reported to play important roles in enhancing plant tolerance to various abiotic stresses (Maghsoudi et al., 2019; Chakma et al., 2021; Öztürk et al., 2021; Özyazıcı, 2021; Apon et al., 2023; Zhang et al., 2023), improving seed germination and seedling development parameters (Ceritoğlu and Erman, 2020; Doğan et al., 2021; Özyazıcı and Açıkbaş, 2021). Salicylic acid also serves as a significant regulator in various physiological processes such as the uptake and transportation of plant nutrients (Hayat and Ahmad, 2007; Farooq et al., 2008; Maghsoudi et al., 2019), the biosynthesis of various enzymes (An and Mou, 2011), stomatal movements (Khan et al., 2003; Hayat and Ahmad, 2007), respiration and photosynthesis (Hayat et al., 2005; Farooq et al., 2008; Janda et al., 2014), sugar metabolism (Dong et al., 2011), and antioxidant enzyme activity (Singh and Gautam, 2013; Torun, 2019). Furthermore, some research has demonstrated its significant potential in mitigating water stress, increasing dry matter accumulation in wheat seedlings in drought-prone areas or under limited soil moisture availability (Singh and Usha, 2003), promoting the growth of corn (Latif et al., 2016) and wheat (Ilyas et al., 2017; El-Hawary et al., 2023), and enhancing seed yield in sesame (Najafabadi and Ehsanzadeh, 2017). However, the responses of plants to SA in seed priming applications are highly dependent on factors such as the applied concentration, plant species and cultivars, plant maturity stage, and environmental conditions (Jayakannan et al., 2015; Poór et al., 2019).

Switchgrass (*Panicum virgatum* L.) is a perennial, warm-season C4 plant native to North America that can be productive for 10 years or more after establishment, can be tolerant of water deficits and low plant nutrient concentrations in the soil, and can adapt to marginal lands (Missaoui et al., 2006; Sokhansanj et al., 2009; Hartman et al., 2011; Candoğan and Geren, 2020; Kesen and Geren, 2020; Hu et al., 2022). In addition to these features of the plant, it has significant genotypic and phenotypic variability (Casler et al., 2004) and thus has a high adaptability (Parrish and Fike, 2005), is tolerant to adverse environmental conditions and has low input (Balsamo et al., 2015) has increased its agricultural value in recent years.

In the cultivation of switchgrass, which is not only used as a bioenergy plant (Aravindhakshan et al., 2010; Wright and Turhollow, 2010; Hartman et al., 2011) but also as a forage crop, pasture plant, and erosion control plant (Mitchell et al., 2001; Das and Taliaferro, 2009; Açıkbaş, 2022), fast and homogeneous germination and seedling emergence are essential regardless of the purpose for which it is grown. Despite its ability to thrive in a wide range of climatic and soil conditions, switchgrass faces some challenges in germination and seedling emergence due to its relatively small seeds, depending on seedbed preparation. Irregular germination and slow seedling growth, especially in the spring, are among the limiting factors in its cultivation. Additionally, common seed dormancy is observed in many warm-season grass species, including switchgrass, owing to the seed coat and embryo structure (Loch et al., 2004; Duclos et al., 2013, 2014). In switchgrass, this seed dormancy and weak seedling viability can pose difficulties in establishment (Evers and Parson, 2003; Loch et al., 2004). Considering that germination is regarded as a critical stage in the plant's development process, pre-sowing seed priming in switchgrass can significantly contribute to improving germination and emergence characteristics by enhancing seed performance. Indeed, some studies have reported the stimulation of germination in switchgrass seeds exposed to specific durations and doses of sulfuric acid (H2SO4), sodium hypochlorite (NaClO), and potassium nitrate (KNO3) (Zarnstorff et al., 1994; Haynes et al., 1997). Pre-sowing seed priming with substances like KNO3, gibberellic acid (GA), and ethylene glycol has been shown to reduce dormancy at low temperatures and improve germination in switchgrass seeds (Madakadze et al., 2000). In addition, it has been reported that seed pre-treatment with synthetic calcium silicate is an effective technique to improve the performance of switchgrass cultivars (Hacisalihoglu, 2008), and exogenously applied gibberellin reduces dormancy at a constant temperature and increases germination in switchgrass cultivars (Duclos et al., 2014).

The aim of this study is to determine the effects of SA priming, a technique within hormonal priming, on germination and seedling development in some switchgrass (*P. virgatum* L.) cultivars.

2. Materials and Methods

The research was conducted in the Laboratory of the Department of Field Crops at Siirt University Faculty of Agriculture.

2.1. Experimental design and applications

The subject of the study consists of SA priming doses (0, 0.10, 0.25, 0.50, 0.75, 1.00, and 1.25 mM) applied to three different switchgrass (*P. virgatum* L.) cultivars (Kanlow, Shawnee, and Trailblazer).

In the research, fifty seeds were used for each replication and experiment was conducted with four replications according to a randomized complete block design. Based on the results obtained from the preliminary sterilization experiment, seed surface sterilization was carried out by immersing the seeds in a 2% NaClO solution for 1 minute to deform the microorganisms on the seed surface. The sterilized seeds were placed between Whatman Grade 2 (Little Chalfont, Buckinghamshire, UK) filter papers in Petri dishes (90 mm x 15 mm). SA solutions prepared according to the doses were applied to each Petri dish with a volume of 3 ml, and the seeds were soaked in SA for 24 hours. The seed/solution ratio in each Petri dish was adjusted to 2:1 g/ml (Johnson et al., 2005).

After priming, the seeds were thoroughly washed with distilled water to clean the entire surface, and then they were roughly dried on blotting paper. Subsequently, they were placed between dry filter papers and dried to their initial moisture content (3±%) for 24 hours (Jatana et al., 2020). The dried switchgrass seeds were then transferred to new Petri dishes, with 3 ml of distilled water added to each Petri dish. The Petri dishes were then placed in an incubator (BINDER, GmbH, Germany) set at a temperature of 25±1 °C for germination.

Germination checks were performed every 24 hours throughout the experiment, and the germination experiment was completed on the 10th day. For the determination of germination in the seeds, the emergence of at least a 2 mm radicle was considered as the germination criterion (Scott et al., 1984; Soleymani and Shahrajabian, 2018).

2.2. The observations and measurements of germination and seedling development

Measurements were obtained from twenty randomly selected plants within each Petri dish. Seeds germinating every 24 hours were counted and Equation 1 of Scott et al. (1984) was used for the determination of the germination percentage (GP).

$$GP = (NGS/TS) \times 100 \quad (1)$$

In the equation, NGS is the number of normal germinated seeds, TS is the total number of utilized seeds.

The mean germination time (MGT) is used to determine the germination day of seeds and was calculated using Equation 2 (Ellis and Roberts, 1981).

$$MGT = \Sigma(NiTi / Ni) \quad (2)$$

Ni is the number of seeds germinated on the Ti day; Ti refers to the number of days from the beginning of germination.

Germination index (GI) was calculated on Equation 3 (Wang et al., 2004), coefficient of uniformity of germination (CUG) by Equation 4 (Bewely and Black, 1994).

$$GI = \Sigma(Gi/Tt) \quad (3)$$

Gi is the germination percentage at the ith day, and Tt is the days of germination test duration.

$$CUG = \Sigma n / \Sigma[(MGT-t)2n] \quad (4)$$

t is the time in days starting from day 0, the day of sowing, and n is the number of seeds completing germination on day t.

The fresh weight of seedlings (SFW) was determined by weighing ten randomly selected seedlings from each Petri dish and calculating the average fresh weight of seedlings. Following this, the fresh seedlings were dried in an oven for 24 hours to determine the average dry weight of the seedlings (SDW).

The seedling vigor index (SVI) was calculated using Equation 5 as reported by Kalsa and Abebie (2012).

$$SVI = GP \times SDW \quad (5)$$

2.3. Statistical analysis

Before conducting the analysis of variance, ArcSin transformation was applied to the germination percentage values (Zar, 1996). The obtained data were subjected to variance analysis following the randomized complete block design, and differences between the means were checked using the TUKEY multiple comparison test (Açıkgöz and Açıkgöz, 2001).

3. Results

3.1. Germination parameters

The effect of SA priming on some germination parameters for seeds of various switchgrass cultivars is presented in Table 1.

As a result of the statistical evaluations, significant differences ($p<0.01$) were observed among switchgrass cultivars in terms of all examined germination parameters. According to results, the variety Kanlow exhibited the highest GP, GI, and CUG values with percentages of 62.19%, 18.74%, and 16.54%, respectively, as the average of SA doses. Additionally, Kanlow cv. emerged as the fastest germinating variety with an average of 3.84 days. Following Kanlow cv. in all germination parameters were the cultivars Shawnee and Trailblazer (Table 1).

Table 1. Some germination parameters of switchgrass cultivars at different SA concentrations*

Cultivars (C)	Salicylic Acid Doses (mM)							
	0.00	0.10	0.25	0.50	0.75	1.00	1.25	Average
	Germination percentage (%)							
Kanlow	56.00 b	66.00 ab	67.33 ab	73.33 a	58.00 ab	60.00 ab	54.67 bc	62.19 A
Shawnee	13.33 g	25.33 efg	51.33 bcd	38.67 cde	26.67 efg	32.00 ef	36.67 def	32.00 B
Trailblazer	34.00 ef	29.33 efg	25.33 efg	38.67 cde	32.00 ef	23.33 efg	21.33 fg	29.14 B
Average	34.44 C	40.22 BC	48.00 AB	50.22 A	38.89 C	38.44 C	37.56 C	
P value	C= 0.0001, SA= 0.0001, CxSA= 0.0001							
	Mean germination time (day)							
Kanlow	4.67 b-g	3.53 ghı	3.50 ghı	3.50 ghı	3.83 d-ı	3.93 d-ı	3.90 d-ı	3.84 B
Shawnee	5.90 a	3.10 hı	3.00 ı	3.73 e-ı	3.77 d-ı	3.60 f-ı	4.23 b-h	3.90 B
Trailblazer	5.27 ab	4.93 a-d	4.07 c-ı	5.27 ab	4.77 a-f	4.87 a-e	5.13 abc	4.90 A
Average	5.28 A	3.85 CD	3.52 D	4.17 BC	4.12 BC	4.13 BC	4.42 B	
P value	C= 0.0002, SA= 0.0001, CxSA= 0.0004							
	Germination index							
Kanlow	13.09 def	21.47 ab	21.94 ab	23.35 a	18.08 a-d	17.77 bcd	15.49 cde	18.74 A
Shawnee	2.69 j	11.34 efg	18.88 abc	11.85 efg	7.59 g-j	10.44 e-h	10.42 e-h	10.46 B
Trailblazer	7.11 g-j	7.02 g-j	7.19 g-j	9.08 f-ı	7.81 f-j	5.16 hıj	4.48 ıj	6.84 C
Average	7.63 E	13.28 BC	16.00 A	14.76 AB	11.16 CD	11.12 CD	10.13 DE	
P value	C= 0.0001, SA= 0.0001, CxSA= 0.0001							
	Coefficient of uniformity of germination							
Kanlow	11.97 de	8.77 abc	9.50 ab	0.87 a	5.43 bcd	15.23 bcd	14.00 cd	16.54 A
Shawnee	2.47 h	10.63 def	17.07 abc	10.53 def	6.50 fgh	9.00 efg	8.70 efg	9.27 B
Trailblazer	6.20 fgh	6.00 fgh	6.20 fgh	7.37 e-h	6.73 fgh	4.90 gh	4.17 gh	5.94 C
Average	6.88 E	11.80 BC	14.26 A	12.92 AB	9.56 CD	9.71 CD	8.96 DE	
P value	C= 0.0001, SA= 0.0001, CxSA= 0.0001							

*: Differences indicated by the same letter in the same column/row/group are not statistically significant, P: Significance level

The effect of SA doses on germination parameters was found to be significant ($p< 0.01$). The application of 0.10, 0.25, and 0.50 mM doses of SA was observed to stimulate germination. Accordingly, as the average of cultivars, the highest GP was determined at the 0.50 mM SA dose (50.22%), and the difference between this dose and the 0.25 mM dose (48.00%) was found to be statistically insignificant. Similar findings were also demonstrated by GI and CUG values. The highest values for both characteristics were identified at the 0.25 mM SA dose; the difference between the 0.25 mM and 0.50 mM SA doses was found to be insignificant for GI and CUG. Overall, the research highlighted that SA applications generally shortened the MGT compared to the control, and the fastest germination occurred at the 0.25 mM dose of salicylic acid (Table 1).

The responses of switchgrass cultivars to different SA doses constitute the main focus of the study. In other words, the reactions exhibited by cultivars depending on SA doses are crucial for the research. Indeed, it has been observed that each germination parameter of the cultivars shows different responses based on SA concentrations. Namely, while the highest germination percentage value in Kanlow and Trailblazer varieties was obtained at 0.50 mM SA dose, with 73.33% and 38.67%, respectively, the highest germination percentage in Shawnee variety was determined at 0.25 mM SA concentration, with 51.33%. Additionally, even with the lowest concentration of SA application after the control in the Kanlow cv. germination significantly increased, while in the Shawnee and Trailblazer cultivars, germination was stimulated at higher doses. This situation led to the statistical significance of the CxSA interaction in terms of germination percentage (Figure 1).

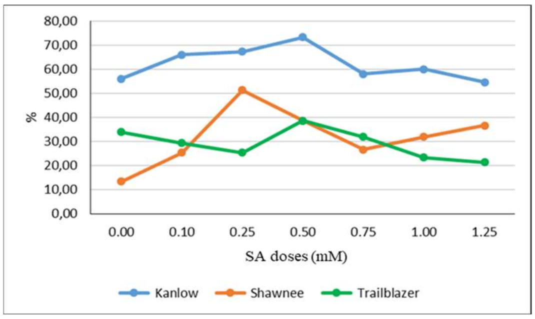

Figure 1. CxSA interaction graph of germination percentage.

The CxSA interaction was also found to be significant ($p<0.01$) in terms of MGT. Accordingly, for the Kanlow cv. the MGT decreased up to the 0.50 mM SA dose, and for the Shawnee and Trailblazer cultivars, it decreased up to the 0.25 mM SA dose; however, subsequent doses led to increases in MGT for all three cultivars. Therefore, cultivars exhibited different responses to SA doses in terms of MGT. This situation is considered the reason for the significant outcome of the interaction (Figure 2).

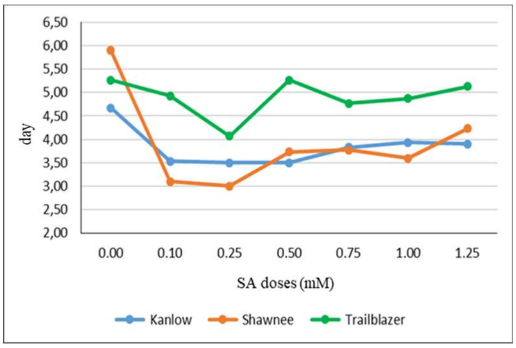

Figure 2. CxSA interaction graph of mean germination time.

Similarly, the CxSA interaction was found to be statistically significant ($p<0.01$) in terms of GI and CUG. For both parameters, the highest values were obtained at the 0.50 mM concentration for Kanlow and Trailblazer cultivars, while the Shawnee cv. reached the highest value at the 0.25 mM dose. The different responses of cultivars to SA doses in this manner led to the significant outcome of the interaction (Figure 3 and 4).

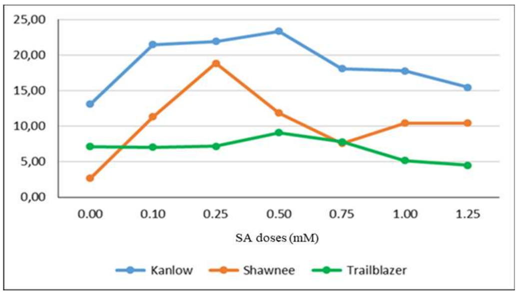

Figure 3. CxSA interaction graph of germination index.

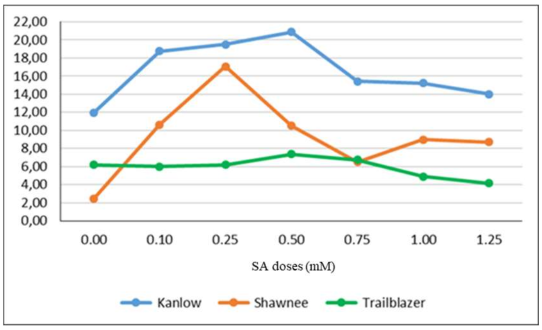

Figure 4. CxSA interaction graph of germination uniformity coefficient.

3.2. Evaluation of seedling growth parameters

Data on the impact of SA priming applications at different concentrations on some seedling growth characteristics of switchgrass cultivars are provided in Table 2.

Table 2. Some seedling characteristics of switchgrass cultivars at different SA concentrations*.

	Salicylic Acid Doses (mM)							
Cultivars (C)	0.00	0.10	0.25	0.50	0.75	1.00	1.25	Average
	Seedling Fresh Weight (mg)							
Kanlow	8.59	8.98	7.23	7.88	8.01	6.77	9.58	8.15
Shawnee	8.58	8.34	8.66	8.82	9.37	8.28	11.70	9.11
Trailblazer	8.68	7.69	10.01	8.71	9.60	8.83	8.97	8.93
Average	8.62	8.34	8.63	8.47	8.99	7.96	10.08	
P value	C= 0.2133, SA= 0.1295, CxSA= 0.4476							
	Seedling Dry Weight (mg)							
Kanlow	0.93 e	1.06 de	0.98 de	1.11 cde	1.00 de	1.04 de	1.05 de	1.02 B
Shawnee	1.06 de	1.77 ab	1.51 a-d	1.92 a	1.89 ab	1.34 b-e	1.38 a-e	1.55 A
Trailblazer	1.78 ab	1.75 ab	1.65 abc	1.75 ab	1.77 ab	1.75 ab	1.71 ab	1.74 A
Average	1.26 B	1.53 A	1.38 AB	1.59 A	1.55 A	1.38 AB	1.38 AB	
P value	C= 0.0005, SA= 0.0036, CxSA= 0.0063							
	Seedling Vigor Index							
Kanlow	52.53 a-d	69.73 a-d	65.87 a-d	81.73 a	57.96 a-d	62.23 a-d	57.50 a-d	63.94 A
Shawnee	14.10 e	44.60 b-e	74.93 ab	74.13 abc	49.73 a-d	43.00 b-e	53.06 a-d	50.51 B
Trailblazer	60.53 a-d	51.33 a-d	42.03 b-e	67.40 a-d	56.63 a-d	39.86 cde	36.70 de	50.64 B
Average	42.39 C	55.22 BC	60.94 AB	74.42 A	54.77 BC	48.36 BC	49.09 BC	
P value	C= 0.0326, SA= 0.0001, CxSA= 0.0006							

*: Differences indicated by the same letter in the same column/row/group are not statistically significant. P: Significance level

There was statistically insignificant variation among cultivars in terms of SFW, with SFW values ranging between 8.15-9.11 mg for the different cultivars. Significant differences were observed among cultivars in terms of SDW ($p<0.01$) and SVI ($p<0.05$). As the average of SA concentrations, the highest SDW was determined in the Shawnee (1.55 mg) and Trailblazer (1.74 mg) cultivars, while the lowest SDW value was found in the Kanlow cv. with 1.02 mg. In contrast, the SVI value was highest in the Kanlow cv., with a value of 63.94, while the SVI values for the Shawnee and Trailblazer cultivars were statistically in the lowest group (Table 2).

While the effect of different SA doses on SFW was insignificant, their effects on SDW and SVI were statistically significant ($p<0.01$). As the average of cultivars, SFW showed variations between 7.96-10.08 mg depending on SA concentrations. In terms of SDW, significant differences among SA doses emerged between the control and the other SA doses. In other words, the differences among the other SA applications, excluding the control, were found to be statistically insignificant. In the study, the SVI increased parallel to the increase in SA concentrations up to the 0.50 mM SA dose, and the highest SVI value, with an average of 74.42, was obtained at this dose. However, the difference between the 0.50 mM dose and the 0.25 mM dose in terms of SVI was statistically insignificant (Table 2).

In the research, the CxSA interaction was found to be significant ($p<0.01$) in terms of SDW and SVI. In terms of SDW, the highest values were obtained with the 0.50 mM application in the Kanlow and Shawnee cultivars, while in the Trailblazer cv., the SA doses had the same effects as the control (Figure 5). Similarly, for SVI, the Kanlow and Trailblazer cultivars showed the highest values at the 0.50 mM dose, while the highest SVI value for the Shawnee cv. was determined at the 0.25 mM dose (Figure 6). The different responses of cultivars to different SA concentrations led to the significant outcome of the interaction.

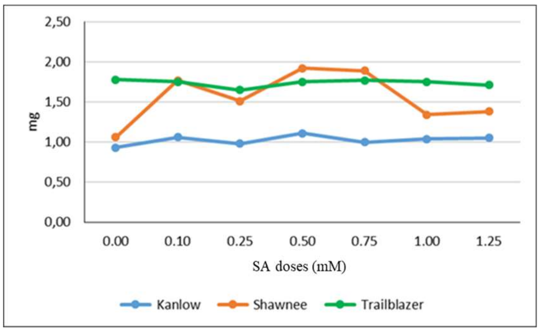

Figure 5. CxSA interaction graph of seedling dry weight.

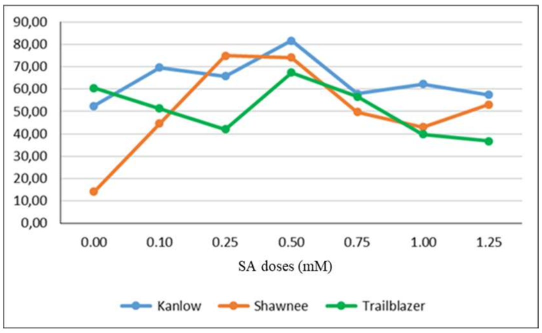

Figure 6. CxSA interaction graph of seedling vigor index.

4. Discussion and Conclusion

Switchgrass, with its ability to thrive in arid conditions and marginal areas where many other plant species cannot be cultivated, holds significant potential for both biofuel and coarse roughage production under limited irrigation conditions, thanks to its high biomass yield. The importance of plant-cultural practices is crucial in realizing this potential. The beginning and success of this application depends on a rapid and uniform seed germination. The small size of switchgrass seeds is a major factor influencing the success of the establishment year and, consequently, the longevity of the plant. Rapid and homogeneous germination and seedling development, along with good soil preparation, are of great importance in this regard. In this sense, the priming technique not only increases germination but also ensures uniform germination and, in many cases, accelerates the germination process. This technique is quite simple and cost-effective, allowing the seed to remain partially moist until the onset of metabolic activity required for seed germination and emergence of the root and plumule (Faisal et al., 2023). This way, the metabolism of endospermic starch is reduced, ensuring the uniform emergence of seedlings (Faisal et al., 2023).

In the results of this study, it was observed that SA priming applied to switchgrass seeds before sowing had significant and positive effects on both germination and seedling development. These effects varied depending on the switchgrass cultivars and the applied SA doses.

According to the research results, the lowland ecotype Kanlow cv. demonstrated superiority, particularly in germination parameters, compared to the upland ecotype Shawnee and Trailblazer cultivars. The observed differences in germination and seedling development parameters among the cultivars can be explained by their genetic differences as they belong to different ecotypes. It is an expected result that varieties with different genetic structures have different germination rates. In addition, there is generally a dormancy problem in switchgrass seeds (Duclos et al., 2014). This condition has been attributed to the interaction between physical and/or physiological mechanisms arising from the characteristics of the seed coat and embryo (Tischler et al., 1994; Haynes et al., 1997; Shen et al., 2001). However, seed dormancy in switchgrass is generally explained by the fact that the seed layers surrounding the embryo can create a physical barrier to radicle emergence (Duclos et al., 2013). Duclos et al. (2014) reported that the dormancy-germination transition is a complex set of factors related to the genotypic nature of the cultivars. Therefore, the difference in germination among cultivars can be associated with genotypic factors caused by seed dormancy.

Hacisalihoglu (2008) Cave in Rock, Dacotah and Kanlow, Duclos et al. (2014) in their study with Cave-in-Rock, Trailblazer, Alamo, Kanlow and Expresso switchgrass varieties, they pointed out a significant difference in terms of GP among the varieties, supporting the findings of our research. In a study on barley with SA priming, significant differences among cultivars were found in GP, MGT, SFW, and SDW (Özkorkmaz and Öner, 2022). Similarly, in SA applications with corn cultivars, significant variability was observed among cultivars in seedling development parameters such as seedling length, root length, SVI, and SFW (Arslan and Gökkaya, 2023).

Pre-seeding seed treatments using plant growth regulators like SA have been utilized (Marthandan et al., 2020). In the current study, SA priming applications significantly affected germination and seedling development parameters. Compared to non-primed seeds, a significant increase and/or improvement were observed in GP, MGT, GI, CUG, SDW, and SVI. When SA applications were examined as the average of cultivars, it was found that the germination percentages of the control group without priming and the 0.75 mM, 1.00 mM, and 1.25 mM SA applications were statistically similar, and concentrations of 0.75 mM and above did not have a positive effect on seed germination. As a result of statistical analysis, the 0.25 mM dose of salicylic acid can be considered the most effective dose for all germination and seedling development parameters. The positive results obtained with salicylic acid priming applications can be explained by the influence of salicylic acid on water uptake, nutrient absorption, stomatal conductance, and cell respiration (Saberi et al., 2011).

There is limited research on priming applications in switchgrass. In these studies conducted with various priming techniques, improvements were achieved in some germination and seedling development parameters, as in the findings of this research. In a study conducted with Cave in Rock, Dacotah, and Kanlow switchgrass cultivars, applying synthetic calcium silicate (MicroCel E) priming was reported to increase GP and shorten the MGT in all cultivars (Hacisalihoglu, 2008). Exposure of switchgrass seeds to 18 M H_2SO_4 for 10 minutes, 5.25% NaClO for 15 minutes, or 0.2% KNO_3 for 14 days has been reported to promote germination (Zarnstorff et al., 1994; Haynes et al., 1997). Similar findings have been obtained in SA priming studies with different plant species. For example, pre-seeding treatments with SA improved GP, MGT, and GI values in soybeans (Glycine max (L.) Merr.) (Doğan et al., 2021) and enhanced germination and early seedling growth in rice (Basra et al., 2006).

In some SA priming studies, different results have been obtained. For example, in the milk thistle (*Silybum marianum L.*) plant, SA applications were reported to decrease GP, GI, and germination energy values (Özyazıcı, 2021). In a study conducted with bitter vetch (Vicia ervilia L.), SA applications did not show statistical differences compared to hydropriming and control, and especially the doses of 1 and 2 mM SA had negative effects on germination and seedling development parameters of bitter vetch (Açıkbaş and Özyazıcı, 2022). In another study, it was reported that some germination and seedling development parameters decreased parallel to the increase in SA dose in corn cultivars (Arslan and Gökkaya, 2023).

Additionally, the results emerging from the CxSA interaction are quite noteworthy. Interestingly, Kanlow seeds had slightly higher GP values both compared to control seeds and other cultivars. In other words, upland ecotype cultivars had less response to SA application. This difference may have arisen from dormancy among seed batches and related physiological differences. Zarnstorff et al. (1994) reported in their study with gibberellins that only one of the two cultivars they examined responded to gibberellin. Madakadze et al. (2000) reported that Dakota cv. did not respond to osmo-priming applications with KNO_3, GA, and polyethylene glycol solutions, while priming applications accelerated germination and total germination in Cave-in-Rock and New Jersey 50 cultivars.

In conclusion, the different responses shown by cultivars in terms of germination and seedling development parameters can be considered as an important finding in the use of them as seed material. As a result of the research, it can be said that salicylic acid has negative effects on germination and seedling development parameters of switchgrass, especially after the 0.50 mM dose. Therefore, considering the dormancy problem of the cultivars, pre-seeding seed treatments with SA may be effective in breaking seed dormancy. In this regard, it has been concluded that applying a dose of 0.25 mM SA to improve germination and seedling development in switchgrass would be appropriate. These findings provide a basis for further physiological and field studies to improve switchgrass establishment.

Conflicts of Interests
Authors declare that there is no conflict of interests

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Statement contribution of the authors
This study's experimentation, analysis and writing, etc. all steps were made by the authors.

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