

ENVIRONMENTAL FACTORS INFLUENCING
THE SEED GERMINATION OF THE WEED
CHENOPODIUM ALBUM L.

Ender Sahin Colak^{1,2}, Dogan Isik¹

Received on February 28, 2025

Presented by H. Najdenski, Member of BAS, on July 29, 2025

Abstract

Weeds are plant species that are highly adapted to their environment and can therefore spread over large areas. *Chenopodium album* L. is one of the most common weeds in most parts of the world. In this study, the effects of environmental conditions that might play a role in the spread and germination of the weed's seeds were investigated. The environmental conditions studied included eight different temperature levels (5, 10, 15, 20, 25, 30, 35, 40 °C), seven different salt concentrations (0, 25, 50, 100, 150, 200, and 250 mmol/l) formed with sodium chloride (NaCl), including the control group, seven different pH values (4, 5, 6, 7, 8, 9, and 10) to characterize large soil areas, and germination in light and dark conditions. The study was conducted in the laboratories of the Plant Protection Department of Erciyes University Faculty of Agriculture, Turkey, in 2022. It was found that the highest germination occurred in the heat-treated seeds when the temperature of 25 °C was applied. The highest germination was observed at pH 8. Approximately 45% germination was observed at the light factor. The highest germination rate was obtained at different salt concentrations in the control group and then at the 25 mM salt application. Examination of the information obtained from the experiments suggests that it is possible to know the factors that can cause or prevent the germination of *C. album* seeds. Knowledge of these factors also has the advantage that the occurrence of weeds can be predicted and more predictable weed control can be performed in advance.

Key words: weed germination, pH, temperature, salinity

Introduction. Given global population growth and the current food needs of the population, it is expected that food supply problems may arise as the world population is expected to reach 9.7 billion people by 2050. It is known that as the population grows, the demand for food will increase, making it more difficult to access food. The currently prevailing intensive urbanization culture and the intensive consumption of natural resources are also factors that limit the possibility of access to food. In addition, there are biotic and abiotic factors that limit product yield. Weeds compete with the cultivated plants and cause losses in product quality and quantity. Although product losses in agricultural production are estimated to be around 30%, it is reported that the damage rate can be as high as 95% if weeds are not controlled [1].

Chenopodium album L. belongs to the Amaranthaceae family and is one of the weed species used in traditional medicine. *C. album* is an annual, broad-leaved herbaceous plant. *C. album* is commonly known as “lamb’s quarter” [2]. *C. album* is a plant species found in most cultivated crops. *C. album* is an edible weed belonging to the genus *Chenopodium* [3]. Plants can have different structures in terms of phenological stages. Germination can be observed in seeds in the same year, as well as the so-called dormancy in weed seeds. Dormancy means that the seed is dormant and contributes to the long-term survival of seeds under unfavourable conditions in the soil. Environmental factors also influence the duration of seed dormancy [4].

Since the seed stage is one of the first stages at which weeds can be scientifically monitored, the seeds of *C. album* were considered in our study. It is known that plants can grow in alkaline and acidic soils. *C. album* is adapted to grow in very different soil structures, therefore the germination of its seeds is observed at different pH values. In this regard, it is possible to find *C. album* in rural areas and almost in most urban areas [1]. It has been found that the most suitable pH range for the development of *C. album* is between 4.5 and 8.3 [5].

In agricultural cultivation, the salt content of the soil is a yield component that harms the plants. Agricultural production takes place in large parts of the world. It is estimated that almost 1 billion hectares of land worldwide are affected by salinization [6]. Soil salinity prevents the plant from reaching the nutrients it needs. *C. album* develops normally in salt concentrations of up to 300 Mm NaCl [7]. *C. album* is a C3 plant in terms of biological structure and is a halophyte [7].

Temperature is also an abiotic stress factor for plants and has important effects on plant growth and development. The influence of the temperature factor on the plant can vary. For example, dormancy of weed seeds is broken for some seeds by chilling and for other seeds by temperature. As a result, the seeds germinate [8]. When evaluating germination under heat stress, *C. album* is a cold-resistant plant, and temperatures close to 0 degrees are known to promote germination.

Another stress factor that affects plant yield and quality is light. Light is necessary for photosynthesis in plants, and it is known that the plant turns to light when there is a lack of light. Light is crucial for the plant in almost all stages of phenology, starting with germination. If we consider the germination event due to dormancy as illumination, it shows that dormancy is triggered by darkness [8].

The study discussed environmental stress factors that have a positive or negative effect on weeds at the seed stage. The effects of temperature, pH, light, and salinity on the germination of *C. album* germination were evaluated and the percentage of seed germination was calculated.

Material and methods. The study was conducted to investigate the effects of light, temperature, pH, and salinity on the germination of *Chenopodium album* L. The seeds of *C. album* used for the study were collected from agricultural fields in Kayseri, Türkiye in 2020 and kept at room temperature in a laboratory until the start of the study. Experiments were conducted in the laboratories of Erciyes University, Faculty of Agriculture, Department of Plant Protection within the scope of the study in 2022.

Seed germination tests. Preparation of the seeds. The seeds of *C. album* used in the study were cleaned of foreign bodies using sieves of different mesh sizes. The seeds were then examined for morphological integrity in the laboratory using a stereomicroscope (Leica ES2) with suitable magnification before being counted. Morphologically perfect-looking seeds were used for the experiments.

Germination of the seeds. In the study, the germination processes of the seeds were carried out under laboratory conditions and in climate chambers (Nüve, TK 600, TK 252). After the counting process, the *C. album* seeds used in the study were exposed to a sodium hypochlorite solution (1%) for one minute and then washed several times with sterile distilled water until the sodium hypochlorite solution was purified [9].

Sterile Petri dishes with a diameter of 9 cm were preferred as germination medium. Thirty seeds of *C. album* were counted per Petri dish and placed in Petri dishes with double-layered filter paper (Whatman No. 1) on the bottom [9]. Seed germination was checked and counted every day from day 0 to day 28, taking the day on which the experiment was started as day 0. The stage at which the grass root of the seeds emerged and reached 2 mm was considered germinated [10,11].

Environmental stress factors. Temperature. In this study, to determine the minimum, maximum, and optimum temperature values for the germination of *C. album* seeds, previously prepared and cleaned seeds were germinated at different temperature values (5, 10, 15, 20, 25, 30, 35 °C). The tests were carried out according to the principle of randomized experimental design with 4 replicates. The germination values were recorded daily and the germination percentages were determined [10]. After the germination counts were completed, the values for germination rate ($G_{\max}$) and germination duration (T_{10} , T_{25} , T_{50} , T_{90}) were

calculated using the following formula:

$$G_{\max} = (G/T) \times 100,$$

where G is the number of total germinated seeds, T is the number of total seeds in the experiment T_{10} = time to %10 of $G_{\max}$ or germinated seeds; T_{25} = time to %25 of $G_{\max}$ or germinated seeds; T_{50} = time to 50% of $G_{\max}$ or germinated seeds; T_{90} = time to 90% of $G_{\max}$ or germinated seeds [9].

Light. To determine the effect of light on the germination of *C. album* seeds, 30 *C. album* seeds, and double-layered filter paper were placed on sterile Petri dishes in light experiments. The experiment was carried out with 4 replicates. In the experiment, environmental chambers were prepared with a day temperature of 25 °C and a night temperature of 15 °C, and the environmental chambers were programmed as 12 hours of light and 12 hours of darkness for 24 hours [12]. The variable temperature of the experiment effectively reflects the natural conditions. To fully reflect the dark conditions, the Petri dishes containing the seeds were wrapped with double-layered aluminum foil, and the dark environment was supported [13]. Germination experiments were conducted for 14 days and germination rates were examined at the end of the 14 days.

pH value. The study was carried out in a climate chamber at different temperatures. To produce a day and night effect on seed germination, a day temperature of 25 °C for 12 hours and a night temperature of 15 °C for 12 hours were determined, and the cabin program was established. Seven different pH values were used for the experiment, namely 4, 5, 6, 7, 8, 9, and 10. Four replicates were performed in each application to increase the accuracy of the experimental results. In the experiment, 30 seeds of *C. album* were placed in each Petri dish with double-layered filter paper. The study was continued for 14 days and at the end of the 14 days the germination percentage was calculated. During the study, the pH of the liquid medium in the Petri dishes was adjusted to the desired value using sodium hydroxide and hydrogen chloride.

Salinity. In the study, germination of *C. album* seeds was investigated with the control group at 7 different salt concentrations (25, 50, 100, 150, 200 and 250 mM). The salt concentrations were obtained by dissolving 0.375, 0.6, 1.45, 2.2, 2.925, and 3.65 g NaCl in pure water, respectively. In the study, 30 previously counted seeds and double-layered filter paper were added to each Petri dish. The study was performed with 4 replicates for each application. Sodium chloride (NaCl) was used to adjust the salt concentrations in the study. In the climate chamber, the daytime temperature was set to 25 °C for 12 hours, and the nighttime temperature was set to 15 °C for 12 hours, so that the study was a simulation of daily temperature fluctuations. As a result of the 14-day experiment, the percentage of germination in the Petri dishes was calculated.

Measurements. The basic parameter measured in this study was the germination percentage of the seeds. The percentage of germinated seeds was de-

terminated by multiplying the result of the ratio of germinated seeds to total seeds by 100.

Statistical analysis. All trials in the study were conducted with four replicates and the data were subjected to analysis of variance using the statistical analysis program R. Whether the difference between the data was statistically significant was tested with a probability of 0.05 using the LSD (least significant difference) test.

Results and discussion. The study investigated the effect of environmental stress factors on the germination of *Chenopodium album* L. seeds. Salinity, pH, temperature, and light were tested as environmental factors.

The influence of pH on seed germination. Germination was observed at all different pH values at which *C. album* seeds were grown in the scope of the study. It was found that the germination capacity of the *C. album* plant, which is already known to occur in wide areas, can persist at different pH values and thus in different soil types. It was observed that the seeds showed the highest germination at pH 8 and that there was a statistical difference from other pH values. The pH at which the seeds germinated the least was pH 4. The study of germination rates revealed that the germination of *C. album* seeds could be higher in alkaline soils than in acidic soils (Fig. 1).

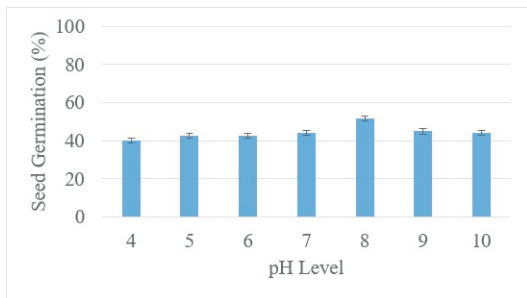


Fig. 1. Effect of different pH levels on germination of *Chenopodium album* L. seeds

The results of this study, in which mature seeds of *Chenopodium album* L. were subjected to germination, suggest that the seeds can germinate in a wide range of soil types. The seeds were tested at pH values of 4, 5, 6, 7, 8, 9, and 10 and germination was observed at all values. The highest germination was observed at alkaline conditions, with the highest germination observed at pH 8. This indicates that the seeds of *C. album* have higher germination in alkaline soils and have a halophytic structure. TANG et al. [4] investigated the effects of environmental factors on the germination of *C. album* seeds. In the study, the seeds germinated under both acidic and alkaline conditions [14]. In one study, pH values between 4 and 10 were applied to the seeds of *C. album*. The results of the study showed that germination decreased significantly when the pH was below 6

and above 8. Seed germination was found to be highest between pH 6 and pH 8 [15]. In one study, proteins were isolated from *C. album* seeds at different pH values. Since the solubility of protein isolates increases under alkaline conditions, the yield of protein isolates obtained from *C. album* varied between 8.12% and 12.22% between pH 9 and pH 12 [16].

Effect of salinity on seed germination. The results of the study show that the seeds of *C. album* can germinate at certain salt concentrations (NaCl) in Petri dishes. It was also found that the germination rate of the seeds decreased with increasing salt concentration. The highest germination rate was found at a concentration of 25 mmol/l after the control group. The lowest germination rate was recorded at 200 mmol/l, while no germination was observed at a salt concentration of 250 mmol/l (Fig. 2).

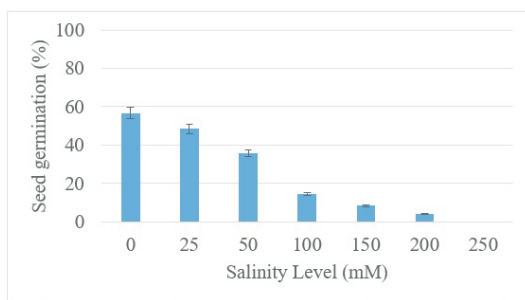


Fig. 2. Effect of different salt (NaCl) concentrations on the germination of *Chenopodium album* L. seeds

In the study, different salt concentrations (NaCl) were added to Petri dishes together with *C. album* seeds, and the germination status was examined. The seeds germinated up to a salt content of 200 mmol/l, with the highest germination rate being achieved in the control group. No germination was observed at a salt concentration of 250 mmol/l. In one study, *C. album* was found to be hardly affected by the increase of salinity in the environment compared to other weed species, and it was estimated that *C. album* could become the dominant species with the increase of salinity in the soil [17]. In a study conducted by TANG et al. [14], it was found that the germination of *C. album* seeds and the amount of salt in the environment are inversely proportional and that salt reduces germination. In one study, 0 (control), 100 mM NaCl, and 300 mM NaCl were applied to *C. album* seeds. The study found that the application of 100 mM NaCl resulted in higher yields than the application of 300 mM NaCl. It was also found that the application of 100 mM NaCl led to better results in terms of plant height than the control and the application of 300 mM NaCl [7]. In the study conducted by BANA et al. [15], it was found that *C. album* seeds could germinate at salt concentrations between 0 mM and 220 mM.

Influence of temperature on seed germination of seeds. The study found that different temperature applications affect the germination of *C. album* seeds. The data obtained by incubating the seeds at different temperatures were subjected to statistical analysis. The statistical analysis revealed that the effects of different temperature applications on seed germination were statistically significant. The seeds of *C. album* did not germinate at the lower and upper temperature values of 5, 10, and 40 °C. The highest germination rate was achieved at 25 °C. At the highest temperatures of 20, 25, and 30 °C, the germination rates were 46.6%, 55.8%, and 41.6%, respectively. The highest germination rate of the seeds was observed on day 28 at 55.8% (Table 1).

T a b l e 1

Effect of different temperature values on germination of *Chenopodium album* L. seeds

Day	Temperature (°C)							
	5 °C	10 °C	15 °C	20 °C	25 °C	30 °C	35 °C	40 °C
1 day	0	0	0	0	0	0	0	0
3 day	0	0	0	0	0	0	0	0
7 day	0	0	0	16.66	20.83	30.83	0	0
14 day	0	0	0	35.83	44.16	42.50	0	0
28 day	0 e	0 e	9.16 c	46.66 b	55.83 a	45.83 b	5.83 d	0 e

*Treatments with the same letter are not statistically different; $P \leq 0.05$

It was found that the lowest germination rate for *C. album* was 35 °C. The study found that the optimum temperature for germination was 25 °C and that the germination rate was high at 20 °C and 30 °C. Statistical analysis showed that there was no difference between 20 °C and 30 °C. The study also calculated the germination times of *C. album* seeds at different temperature values (T_{10} , T_{25} , T_{50} , T_{90}).

It was found that the germination of *C. album* seeds did not exceed the high temperature of 35 °C. The germination period of the seeds was also examined as part of the study. In the germination time studies, it was found that seeds germinated for a minimum of 1.5 days and a maximum of 28 days (Table 2).

As part of the study, the seeds of *C. album* were exposed to different temperature levels in Petri dishes in different climate chambers. According to the results of the study, it was found that no germination occurred when 5, 10, and 40 °C were applied. The highest germination rate was observed at 25 °C. Although high germination was also observed at 20 °C and 30 °C, there was no statistically significant difference between the two temperature values. One study found that 12-hour temperature cycles of 15 °C during the day and 5 °C at night prevented the germination of *C. album* [18]. ALTENHOFEN [18] found that the optimum germination temperature for *C. album* is between 15 °C and 25 °C. In the study

T a b l e 2

Effect of different temperature values on the germination rate and germination time of *Chenopodium album* L. seeds

Temperature	G _{max}	T ₁₀ (day)	T ₂₅ (day)	T ₅₀ (day)	T ₉₀ (day)
5 °C	0 ± 0 f	0 ± 0 b	0 ± 0 c	0 ± 0 e	0 ± 0 e
10 °C	0 ± 0 f	0 ± 0 b	0 ± 0 c	0 ± 0 e	0 ± 0 e
15 °C	9.17 ± 3.3 d	7 ± 8.1 a	21 ± 8.1 a	28 ± 0 a	28 ± 0 a
20 °C	46.67 ± 2.2 b	7 ± 0 a	7 ± 0 b	14 ± 0 b	28 ± 0 a
25 °C	55.83 ± 1 a	7 ± 0 a	7 ± 0 b	14 ± 0 b	24.5 ± 4 b
30 °C	40 ± 4.2 c	7 ± 0 a	7 ± 0 b	7 ± 0 c	17.5 ± 4 c
35 °C	5.83 ± 1.8 e	0 ± 0 b	1.5 ± 1 c	3 ± 0 d	3 ± 0 d
40 °C	0 ± 0 f	0 ± 0 b	0 ± 0 c	0 ± 0 e	0 ± 0 e

*Treatments with the same letter are not statistically different; $P \leq 0.05$

conducted by Tang et al. [14], it was found that *C. album* seeds germinated at temperatures between 15 °C and 40 °C.

Effect of light on seed germination. The study investigated the effect of light on seed germination of *C. album* seeds. The results of the study showed that germination was very low in darkness, while germination increased under light conditions. It was also observed that germination increased when the seeds were on the soil surface or near the surface in terms of access to light. Therefore, it can be said that the weed seeds are brought to the soil surface by superficial tillage and their germination is promoted by the effect of light.

The study investigated the influence of the light factor on the germination of *C. album* seeds. The seeds were placed in Petri dishes in climate chambers under light and dark conditions and their germination was monitored. In the dark environment, the plants hardly germinated at all, while a germination rate of 45.83% was observed under light conditions. According to the results of the study conducted by Altenhofen [18], the germination of *C. album* was found to be promoted under light conditions. One study investigated the dimensional effect of light on plant seeds and found that light is very important for the germination of plants with small seeds, such as *Lactuca sativa* L. (lettuce) and *Arabidopsis thaliana* (L.) Heynh (thale cress) [4]. In another study, the application of red light was reported to stimulate the germination of *C. album* seeds [4]. In one study, it was found that the light factor was effective in the germination of *C. album* seeds and that almost no germination was observed under dark conditions [14].

Conclusion. Following the main objective of the study, the effect of environmental factors (temperature, salt, pH, and light) on the germination of *C. album* seeds was investigated. In this study, environmental factors were found to affect seed germination. By knowing which factor determines the germination rate of seeds, it is possible to predict the emergence of weeds in advance.

This is an advantage in controlling the propagation and spread of *C. album* plants. Environmental factors can also promote the germination of dormant *C. album* seeds. Considering the data obtained from this study, it can be assumed that environmental factors can be used both to monitor germinable seeds and to determine a strategy to control seeds and dormant seeds to germinate.

Acknowledgements. We would like to thank the Proofreading & Editing Office of the Dean for Research at Erciyes University for the copyediting and proofreading service for this manuscript.

REFERENCES

- [1] HUSSAIN I., M. N. MALIK, M. A. NADIM (2022) Study on biotic stress in cereals and non-cereals through phyto-toxicity caused by *Chenopodium album*, Pakistan J. Weed Sci. Res., **28**(4), 405.
- [2] ARORA S., P. ITANKAR (2018) Extraction, isolation and identification of flavonoid from *Chenopodium album* aerial parts, J. Tradit. Complement. Med., **8**(4), 476–482.
- [3] SINGH R., S. SINGH, D. C. SAXENA (2021) Studies on standardization of alcohol aided starch extraction process from *Chenopodium album* and its characterization, J. Food Meas. Charact., **15**(6), 5379–5391.
- [4] TANG D. S., M. HAMAYUN, Y. M. KO et al. (2008) Role of red light, temperature, stratification and nitrogen in breaking seed dormancy of *Chenopodium album* L., J. Crop Sci. Biotechnol., **11**(3), 199–204.
- [5] SINGH S., A. SINGH, S. S. HALLAN et al. (2023) A compiled update on nutrition, phytochemicals, processing effects, analytical testing and health effects of *Chenopodium album*: A non-conventional edible plant (NCEP), Molecules, **28**(13), 4902.
- [6] HUSSAIN M. I., A. J. AL-DAKHEEL, M. J. REIGOSA (2018) Genotypic differences in agro-physiological, biochemical and isotopic responses to salinity stress in quinoa (*Chenopodium quinoa* Willd.) plants: Prospects for salinity tolerance and yield stability, Plant Physiol. Biochem., **129**, 411–420.
- [7] ATTAR A. Z., T. AHMED, A. KATO et al. (2023) Understanding impact of heat, drought, and salinity stresses on growth and physiological attributes of *Chenopodium album* under field conditions, Plant Growth Regulation, **100**(1), 107–118.
- [8] ADHIKARY P., P. TARAI (2013) Effects of temperature and gibberellic acid (GA3) on seed germination of *Vicia sativa*, *Chenopodium album* and *Physalis minima*, Int. J. Agric. Environ. Biotechnol., **6**(4), 629–632.
- [9] FARAJ A., E. S. COLAK, D. ISIK (2023) Environmental factors influencing *Lolium temulentum* L. (Darnel ryegrass) seed germination, Annali di Botanica, **13**, <https://doi.org/10.13133/2239-3129/17899>.
- [10] GÖNCÜ G. B. (2013) Effects of different CO₂ rates on the development, competition and herbicide sensitivity of some important weeds in maize (*Zea mays* L.), Master's Thesis, Adnan Menderes University, Institute of Science, (in Turkish).
- [11] ISIK D., H. MENNAN, M. CAM et al. (2016) Allelopathic potential of some essential oil bearing plant extracts on common lambsquarters (*Chenopodium album* L.), Rev.

- Chim., **67**(3), 455–459.
- [12] SINGH S., M. SINGH (2009) Effect of temperature, light and pH on germination of twelve weed species, *Indian J. Weed Sci.*, **41**(3–4), 113–126.
 - [13] BASKIN C. C., J. M. BASKIN (2014) *Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination*, 2nd Edn, San Diego, Academic Press, 150–162.
 - [14] TANG W., H. GUO, J. YIN et al. (2022) Germination ecology of *Chenopodium album* L. and implications for weed management, *PloS ONE*, **17**(10), e0276176.
 - [15] BANA R. S., V. KUMAR, S. SANGWAN et al. (2022) Seed Germination Ecology of *Chenopodium album* and *Chenopodium murale*, *Biology*, **11**(11), 1599.
 - [16] MIR N. A., C. S. RIAR, S. SINGH (2019) Effect of pH and holding time on the characteristics of protein isolates from *Chenopodium* seeds and study of their amino acid profile and scoring, *Food Chem.*, **272**, 165–173.
 - [17] GHIRARDELLI A., M. SCHIAVON, G. ZANIN et al. (2021) Short-term responses to salinity of soybean and *Chenopodium album* grown in single and mixed-species hydroponic systems, *Agronomy*, **11**(8), 1481.
 - [18] ALTENHOFEN L. M. (2009) The effects of light, temperature, after-ripening, nitrate and water on *Chenopodium album* seed germination, Master's Thesis, Iowa State University.

¹Department of Plant Protection, Faculty of Agriculture, Erciyes University, Kayseri, Türkiye
e-mails: endersahin@erciyes.edu.tr, <https://orcid.org/0000-0002-8083-1175>
dogani@erciyes.edu.tr, <https://orcid.org/0000-0002-0554-2912>

²Department of Plant Protection, Graduate School of Natural and Applied Sciences, Erciyes University, Kayseri, Türkiye