

Article

Germination Responses of Common Chickweed (*Stellaria media* (L.) Vill.) to Water Potential, Salinity, and pH and Its Association with Forage Wheat Yield and Nutritive Composition

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Abstract

Common chickweed [*Stellaria media* (L.) Vill.] is a common winter annual weed in forage wheat (*Triticum aestivum* L.) fields in California. Lack of control of this species by commonly used herbicides has raised concern about its presence in larger numbers and ability to persist and compete with crops causing yield and crop nutritive composition losses. However, very little is known of its germination ecology, competitiveness, and the resulting effect on the yield and quality of forage wheat. Laboratory studies were conducted to develop an understanding of its germination response under a range of simulated osmotic stress, salinity, and pH conditions. Observational studies in grower fields were also conducted to estimate forage wheat yield and some nutritive components (crude protein, acid detergent fiber, neutral detergent fiber, starch, and ash) in infested and un-infested areas of the fields. The laboratory germination studies showed that common chickweed seeds were very sensitive to osmotic stress but had mild-to-moderate tolerance to salinity and preferred neutral pH rather than alkaline or acidic conditions. Germination was reduced by approximately 50% at -0.133 MPa matric water potential as well as in 14.5 dS m^{-1} electrical conductivity solution. Fresh weight of forage wheat at harvest was 22 to 44% (depending on crop moisture content) lower and dry biomass was approximately 12% lower in the areas infested with common chickweed compared to the areas without any weeds. The crude protein, acid detergent fiber, and neutral detergent fiber levels of common chickweed were 13.6%, 35%, and 46%, respectively, and it did not reduce the measured nutritive composition of forage wheat. In conclusion, we determined the ideal water potential, salinity, and pH conditions for common chickweed germination and that infestations of this species could reduce yield but not the nutritive components of forage wheat measured in this study.

Keywords: water potential; salinity; pH; crude protein; acid detergent fiber; neutral detergent fiber; starch; ash



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1. Introduction

Small grains—wheat (*Triticum aestivum* L.), triticale ($\times$ *Triticosecale*), rye (*Secale cereale* L.), oats (*Avena sativa* L.), and barley (*Hordeum vulgare* L.)—are important forage crops grown in California that play a significant role in animal daily diets and thus human diets,

contributing to global food security [1]. Weeds are regarded as the most predominant pest constraint of yield and quality in these small grain cropping systems in California [2].

Native to Eurasia, common chickweed [*Stellaria media* (L.) Vill.] has been increasingly observed invading triticale and wheat fields in the southern San Joaquin Valley (SJV) of California (Figure 1), in part due to the failure of common herbicides in controlling it [3]. Common chickweed was recently reported to be cross-resistant to several chemical classes of a common herbicide mode of action, acetolactate synthetase (ALS) inhibitor, used in these small grain forage production systems [4].



Figure 1. Common chickweed (*Stellaria media* L.) infestation in a forage wheat field in the San Joaquin Valley of California.

Alfalfa and small grains, including wheat, triticale, barley, oats, and rye, are widely cultivated for hay or silage throughout most of California [1]. In 2023, approximately 390,521 hectares of forage crops were planted in California, yielding 4,882,468 metric tons [5]. The SJV produces a large share of California's small grains, most of which are irrigated and grown in rotation with other field and vegetable crops. In the SJV, which is home to most of the state's dairy cows, small grain forage thus plays a crucial role in providing high-quality forage during the winter season [1]. Small grains are valuable due to high yields, flexibility in rotations, rapid adaptation to water and market changes, and their ability to recycle waste products [1]. In recent years small grain production has been fluctuating due to abiotic and biotic factors. Weeds have been one of the most predominant biotic constraints affecting quality and yield of small grain production. The most common broadleaf and grassy weeds that infest SJV small grain forage crops are shepherd's purse (*Capsella bursa-pastoris* (L.) Medik), London rocket (*Sisymbrium irio* L.), fiddleneck (*Amsinckia* sp.), burning nettle (*Urtica urens* L.), Italian ryegrass (*Festuca perennis* (L.) Columbus & J.P. Sm., syn. *Lolium multiflorum* Lam.), mallow (*Malva parviflora* L.), and wild oats (*Avena fatua* L.) [1]. Amongst weeds, common chickweed has been perceived by growers and pest control advisors as an increasing problem in small grain forage crop production, due to the decline in effectiveness of some of the common herbicides traditionally used to control them. However, there is very limited information on the biology, ecology, and

competitiveness of this species in the SJV as it was not perceived to be a problematic weed until recently. Thus, better understanding of the biology, ecology, and competitiveness of this weed species is urgent.

Common chickweed, belonging to the Caryophyllaceae family, is a homogamous, self-pollinated, and self-fertilized winter-annual species that is considered a weed of grain fields, cultivated areas, pastures, roadsides, lawns, and gardens [6–8]. The flowers of common chickweed that are produced in the winter are generally cleistogamous [8]. A study [9] reported that common chickweed is an allotetraploid ($2n = 44$). The reported 5–6-week life cycle of this species allows it to flower and set seed very rapidly [10], making seed the chief means of reproduction [7]. It can produce up to 30,400 seeds per plant [8] that can remain viable in the soil for 7–8 years [10]. Thus, if plants of this species are allowed to escape, it will have long-term implications for weed seed bank dynamics and future infestations, compromising weed management programs. Seed germination usually occurs from January to early May [10] in cool soil temperatures ranging from 12 to 20 °C [6–8,10]. The species has been observed to germinate in late fall or early winter in California [10]. Its polymorphic characteristics have enabled it to adapt to various growing conditions [9]; however, it thrives in cool temperatures with moist soils high in nitrogen and a neutral pH [10]. This species is reported to be highly drought-sensitive [7].

Although the origin of common chickweed is Eurasia, in recent years, its adaptable characteristics to various environmental conditions, except drought, have allowed it to thrive and spread worldwide [6–8]. It is believed that this species found its way into America through European explorers and immigrants using the plant as a medicinal herb and through seed contamination of grain shipments. Furthermore, the species has colonized most of North and South America's grain farmland and residential yards with its numerous, tiny, easily dispersed seeds [8]. In the SJV, seeds of common chickweed have made their way into various small grain fields presumably through contaminated forage feed and dairy manure applications, as reported in other areas of the U.S. [11]. Notably, small grain forage farmers in the SJV usually harvest their fields that are heavily infested with common chickweed and feed the contaminated forage to dairy cows, which makes the forage quality of this species a question of interest.

The short period between germination and flower production in common chickweed's life cycle can make it difficult to control in small grain crops, especially in wheat and triticale. In these crops, common chickweed is often observed as a low-growing species under the crop canopy where there is partial shade [12]. In wheat and triticale, it is essential to control common chickweed before the crop reaches the jointing stage [2]. A delayed herbicide application can result in ineffective control of the species due to the crop canopy shielding it from herbicide contact [13]. Control of common chickweed in small grain crops should be carefully monitored, especially those that receive a top-dressing of nitrogen fertilizer in spring, because this species is a high nitrogen consumer [7].

Small grain forage crops are grown under various conditions, and a broad spectrum of weed species may be present in any field [13]. For this reason, it is essential to control weeds in small grains because weeds can compete and reduce the grain or forage yield, impede harvest operations late in the season when they mature later than the grain, and contaminate the grain crop with their seeds, making extra cleaning necessary and causing loss of return to the grower due to price dockage [2,13].

Interestingly, many of the competition studies in small grain crops have been limited to weeds other than common chickweed. For example, it was reported that a wild oat (*Avena fatua*) density of 140 m⁻² reduced barley and wheat yield by 27% and 39%, respectively [2]. Similarly, one wild radish (*Raphanus raphanistrum* L.) plant per 0.09 m² when emerging with the crop reduced wheat yield by as much as 66% [13].

Common chickweed is reported to be not as problematic as the above weeds in wheat, triticale, barley, and alfalfa (*Medicago sativa* L.) cropping systems and can be easily outcompeted by tall crop cultivars [6,7]. However, large populations of common chickweed can smother and shade crop seedlings by forming a dense mat of interwoven shoots [6,7], reducing yield and removing moisture and nutrients from the soil [7,12]. Its population density may be quite high as 80 to 100% of the area between potato (*Solanum tuberosum* L.) and barley crops was reported to be covered by common chickweed plants [6]. The growth rate of common chickweed exceeds that of barley, and it absorbs nitrogen more efficiently, outcompeting cereal and oilseed crops for resources, thus reducing yield and quality [12]. In a study in the U.K., the yield of oilseed rape (*Brassica napus* L. ssp. *oleifera* (D.C.) Metzg.) was reduced by 5% due to an average common chickweed density of 37 plants m⁻² [14]. The competitive ability of common chickweed in small grain cropping systems is often underestimated due to conflicting evidence and variables. As discussed above, most of the research on common chickweed was conducted in Europe and there are no published reports on this species in the SJV or in California, in general. The SJV is a semi-arid area with soil salinity and high pH soil issues. Thus, addressing the possible interference dynamics of common chickweed in SJV small grains and its possibility to germinate, establish, grow, and compete is essential. However, it is difficult to conduct germination studies involving stress factors under field conditions. Therefore, most of the studies on the effect of stress factors on seed germination have been conducted under controlled conditions in the laboratory.

The objectives of this study were to: (i) determine the germination potential of the SJV common chickweed populations under varying levels of pH (5, 6, 7, 8, and 9), salinity (electrical conductivity of 0, 2.5, 5, 10, 15, 20, and 25 dS m⁻¹), and moisture content (water potential of 0, -0.07, -0.149, -0.51, -1.09, -1.88, -2.89, -4.12 MPa) to predict their adaptability and ability to germinate in different regions of the SJV, and (ii) determine the interspecific competitive effect of common chickweed on forage wheat yield, biomass, and nutritive composition in existing farmer fields with infestation of this species.

2. Materials and Methods

2.1. Seed Germination Studies

The common chickweed seeds were collected from four different agricultural locations of Kings and Tulare counties of California. Seed collection locations showed a range of soil conditions and crop management strategies. One field was an organic pistachio orchard with high soil type variability. Dominant soil series were Excelsior (coarse-loamy, mixed, superactive, calcareous, thermic Typic Torrifluvents) and Grangeville (coarse-loamy, mixed, superactive, thermic Fluvaquentic Haploxerolls), which are moderately well-drained and somewhat poorly drained sandy loams, respectively. The other three sites were double-cropped silage wheat and silage corn (*Zea mays* L.) fields. One of these sites was characterized by the Colpien series (fine-loamy, mixed, superactive, thermic Calcic Pachic Haploxerolls), a well-drained loam. The remaining two fields were characterized by the Crosscreek series (fine-loamy, mixed, superactive, thermic Natric Durixeralfs), ranging from a well-drained loam to sandy clay loam derived from the Kai series which originally formed from granite alluvium. Germination of these locally collected seeds were tested under a range of moisture, pH, and salinity levels at the Jordan Agriculture Research Center of California State University, Fresno, in a controlled-environment growth chamber (Conviron CMP 6010, Conviron, Winnipeg, MB, Canada) at 20/15 °C day/night temperature for a 12 h cycle. The solution preparations for salinity, pH, and water potential studies were as described below and separate studies were conducted for each of these variables.

Salinity studies: Salinity solutions with electrical conductivity values of 0, 2.5, 5, 10, 15, 20, and 25 dS m⁻¹ were prepared using laboratory-grade sodium chloride (NaCl). The

respective amounts of NaCl, 0.73 g, 1.21 g, 2.92 g, 4.385 g, 5.845 g, and 7.305 g, were mixed in 1000 mL of deionized water to achieve the desired electrical conductivity levels described immediately above. An electrical conductivity meter from Spectrum Technology Inc. was used to verify the electrical conductivity levels of each solution.

pH: The varying pH (5, 6, 7, 8, and 9) solutions were prepared using different buffer solutions. Citrate buffers, consisting of citric acid and sodium citrate, were used to achieve pH level 5. For pH levels 6 and 7, a potassium phosphate buffer with monobasic dihydrogen phosphate and dibasic monohydrogen phosphate was used. To create a pH 8 solution, a tris-borate EDTA solution was used. To achieve pH level 9, a tris-HCl buffer consisting of tris(hydroxymethyl)aminomethane and hydrochloric acid was used. All the required solutions were prepared using the necessary chemicals mixed with deionized (DI) water. Different buffers had to be used for the various levels to obtain the desired pH level. Each of the pH solutions were verified using a pH meter (UltraBasic Benchtop pH Meter, Denver Instrument Company, Arvada, CO, USA).

Water potential: Water potential solutions of different levels (−0.07, −0.149, −0.51, −1.09, −1.88, −2.89, and −4.12 MPa) were prepared using polyethylene glycol (PEG 6000) at room temperature (20 °C). Each solution was mixed with 100 mL of DI water using 5, 10, 20, 30, 40, 50, and 60 g of polyethylene glycol to achieve the respective water potentials described immediately above. The corresponding water potentials were verified using a thermocouple psychrometer (HR 33-T Dew Point Microvoltmeter connected to a C-52 Sample Chamber, Wescor Inc., Logan, UT, USA), as described by Shrestha et al. [15].

All three germination studies were conducted separately in a similar format. The experiments were arranged in a completely randomized design with five replications of each treatment level, and the studies were repeated twice. Seeds from the same collections were used for all the studies. Twenty seeds of common chickweed were placed in a 9 cm diameter Petri dish containing seed germination paper (Blue Blotter Circle seed germination paper, Anchor Paper Co., St. Paul, MN, USA). For each Petri dish, 10 mL of the respective varying solution levels of pH (5, 6, 7, 8, and 9), salinity (electrical conductivity of 0, 2.5, 5, 10, 15, and 20 dS m^{−1}), and moisture content (water potential of 0, −0.07, −0.149, −0.51, −1.09, −1.88, −2.89, and −4.12 MPa) were added. The germination process was monitored by evaluating the Petri dishes every 3–4 days for 21 days total. A seed was considered germinated when the radicle and plumule emerged. Germinated seeds were counted and removed. After 21 days, seeds that did not germinate from the original dish were transferred to a new Petri dish with germination paper and 10 mL of DI water to test the viability of seeds for approximately seven days. This process helped in estimating the viability of the seeds that failed to germinate under each treatment [15]. The total number of germinated seeds were then expressed as a percentage of the overall viable seeds [15].

2.2. Common Chickweed–Forage Wheat Competition Studies

An observational study was conducted in three grower forage wheat fields in the Kings, Tulare, and Fresno counties with a history of problematic common chickweed populations in 2024 and 2025. The study was conducted in the same fields both years. All of the fields had very similar environmental and management conditions. Each of the fields had been under a double-crop silage wheat and silage corn (*Zea mays* L.) rotation. Wheat was established by surface irrigation, and weed management at each site was conducted with the use of at least one in-season postemergence herbicide application. All of the fields were conventionally tilled between crops using full-width tillage equipment. Fertility was managed through application of dairy manure in process wastewater via blended irrigation. Data from two local weather stations in the region of the three sites tracked similar, fair growing conditions in growing seasons of both years from October

through May. Cumulative precipitation in both years ranged from 229 to 254 mm and daily minimum and maximum air temperatures ranged from -1.7 to 30 °C. The region is characterized by semi-arid hydrology and mild winters, which provide ample heat for crop growth and development but require supplemental irrigation to achieve acceptable yields. The experiment was considered as an imposed pseudo-completely randomized block design, with the site as the block and presence or absence of common chickweed in the plots as treatment, for facilitation in data analysis. Twenty random samples each were collected from plots infested with common chickweed and from weed-free areas of 2.023 hectares of these dairy farms at the forage harvest stage—approximately Feekes 11.2, or “soft dough.” The sampling was done a day or two prior to the actual harvest of the crop as this is the desired stage for forage wheat harvest by the farmers in this area. Wheat plants were sampled from 0.25 m^2 quadrat areas by clipping them at 10.16–15.24 cm above the soil surface. The samples were bagged and transported to the lab where they were separated into wheat and common chickweed. The fresh weights of the wheat and chickweed samples were recorded separately, dried in a forced-air oven at 65 °C for 72 h, and their total above-ground dry biomass weights were taken to estimate dry matter (DM) yield. Wheat plant height was measured with a measuring stick from 10 random plants in each plot area from the plant base to the tip of the spike, excluding awns, at harvest. Spike height was measured with a ruler from the same ten randomly selected plants at harvest. Stand count was performed by counting the total number of wheat plants within a quadrat and calculated on a m^2 area basis. All these measurements were based on the protocols of Ayana [16]. Representative subsamples, maintaining the biomass proportions of wheat and common chickweed, were taken from the harvested dry biomass samples. The subsamples were ground in a Willey Mill (Thomas–Willey Laboratory Mill, Philadelphia, PA, USA) grinder with a 1 mm screen (Cyclons Mill UDY Mfg. Fort Collins, CO, USA). The samples were further ground to a finer sample in a FOSS CT 293 Cyclotec™ plant tissue grinder (FOSS, Hillerød, Denmark) with a 0.01 mm mesh, then placed into plastic Ziplock bags. Twenty ground samples in 2024 and 10 samples in 2025 of wheat alone, wheat and common chickweed mixture, and common chickweed alone were included for nutritive composition analysis. The ground wheat samples were analyzed for forage nutritive composition (crude protein, acid detergent fiber, amylase neutral detergent fiber, starch, and ash) in the Graduate Laboratory at California State University, Fresno, using a near-infrared spectroscopy (NIRS) analyzer (Foss NIRS™DS2500 F, FOSS, Denmark). This device is equipped with pre-programmed calibration curves for various forages, and our team selected the “corn and wheat silage” option to conduct NIRS forage quality assessment of all of the samples. NIRS is a popular method for assessing forage quality, including components like nitrogen, moisture, fiber, structural carbohydrates, amino acids, and minerals [17–21]. When properly calibrated, NIRS can match the accuracy of traditional wet chemistry methods for analyzing forage nutrition [19,20]. NIRS was utilized to evaluate Italian ryegrass (*Lolium multiflorum*) in South China [20]. Although *Lolium multiflorum* has been studied as a forage crop using NIRS, it is considered a weed in small-grain systems in the SJV, demonstrating the versatility of NIRS in forage quality assessment of traditional feed crops and weeds alike. However, we acknowledge that the literature on the calibration of NIRS for common chickweed and wheat-common chickweed is not available and the accuracy of the values generated compared to standard wet chemistry needs to be further determined.

2.3. Data Analysis

The statistical software SAS (Version 9.3.4 SAS Institute Inc. Cary, NC, USA) was used to analyze data from the experiments using the appropriate analysis of variance (ANOVA)

model at a significance level of 0.05. All the experimental data sets were first tested to verify whether the assumptions of ANOVA were met using Shapiro–Wilk’s test for normality and Levene’s test for homogeneity of variance at the 0.05 level of significance. If data failed to meet the assumptions, appropriate transformations were used. The means were separated using Fisher’s Least Significant Difference (LSD) test when ANOVA indicated significant differences at the 0.05 level. The data for water potential, salinity, and pH experiments included fixed and random effects, and all possible interactions between the fixed and random factors were analyzed. In the various analyses, common chickweed seed collection site, water potential, salinity, and pH treatments were considered as fixed effects while replication and repetition of the experiment were considered as random effects. Data on percent seed germination for water potential, salinity, and pH studies were arcsine-square-root transformed to meet ANOVA assumptions before analysis. Regressions were graphed in SigmaPlot v.15 using a three-parameter sigmoidal model. There were no significant interactions between the seed collection location of common chickweed and the treatments for either water potential, salinity, or pH; therefore, the results of the four populations were combined and analyzed.

In the crop–weed competition study, fresh and dry biomass of infested and non-infested forage wheat did not meet the assumption of normality for ANOVA. All possible transformations failed for the forage fresh biomass data; therefore, a nonparametric test (Cochran–Mantel–Haenszel Statistics—based on rank scores) was conducted in SAS on the fresh-weight biomass data, while the dry biomass data was square-root transformed and analyzed by ANOVA because it met the assumptions of ANOVA after transformation. Data on wheat plant and spike height did not meet the ANOVA assumptions, so the same nonparametric test stated above was applied. The plant stand count data met the assumptions of normality; hence, an ANOVA was conducted for this variable. In the forage quality study, data were square-root transformed since they were not normal and analyzed by the ANOVA method. In this study, infestation and non-infestation of common chickweed were considered as the treatments (fixed effects) while location and year were considered as random effects. When there were no interactions between the treatments and the experimental round or year, the data from the two years were combined and reanalyzed.

3. Results

3.1. Effects of Water Potential Levels on Germination of Common Chickweed Seeds

Germination of the common chickweed seeds in response to the water potential (Ψ) treatments were consistent between the two experimental repetitions because there were no significant interactions ($p > 0.05$) between the repetition of the study and Ψ treatments. Therefore, the data for the experimental repetitions were combined and reanalyzed.

Germination of common chickweed seeds progressively decreased as Ψ decreased (Figure 2). Germination declined rapidly even with a relatively small decrease in Ψ . For example, percent germination was 30% lower at -0.07 MPa compared to 0 MPa. A continuous decline in percent germination occurred thereafter as Ψ decreased from -0.07 to -0.149 MPa, followed by very-low germination at -0.51 MPa with no further germination at -1.09 MPa. The germination at -0.07 , -0.149 , and -0.51 MPa was approximately 70, 50, and $<5\%$, respectively. The three-parameter nonlinear sigmoidal regression model indicated that the Ψ at which germination was decreased by 50% was approximately -0.133 MPa. Although common chickweed seems to be very sensitive to osmotic stress during germination, it was observed that some seeds germinated even under high-osmotic-stress conditions. However, it is not known if the seedlings would continue to grow and reproduce under these conditions.

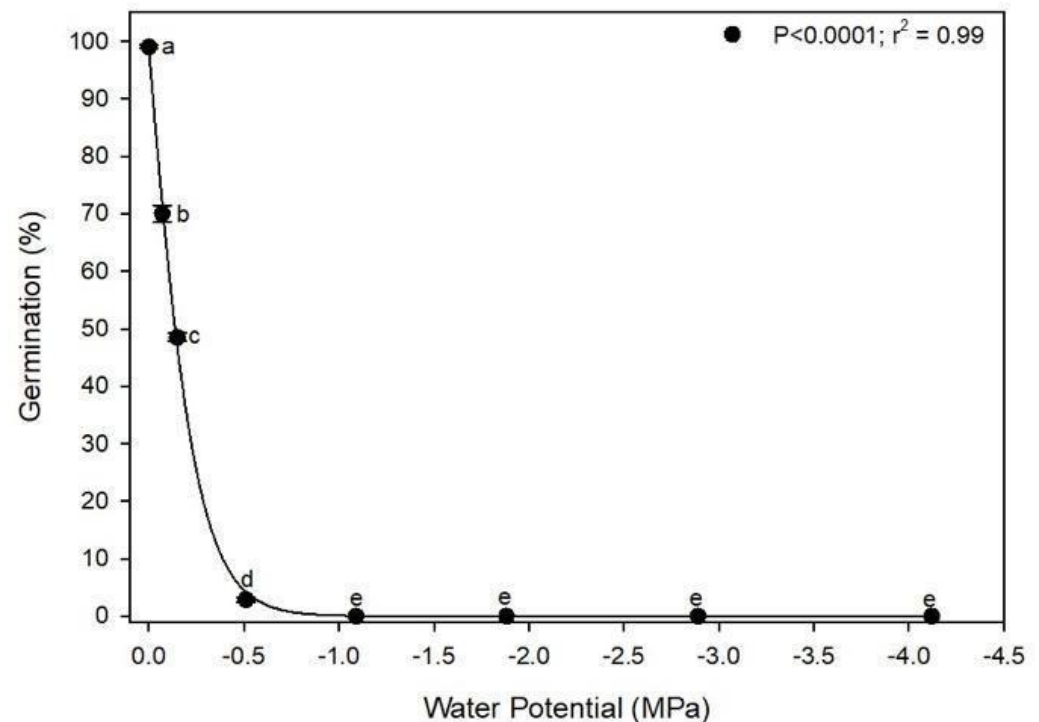


Figure 2. Percent germination (mean $\pm$ SEM) of common chickweed seeds in response to various water potential levels simulated by polyethylene glycol. The means for the treatments with different letters indicate significant difference according to Fisher's Least Significant Difference test at $\alpha = 0.05$. The solid curve represents the fitted three-parameter nonlinear sigmoidal regression model.

3.2. Effects of Salinity (NaCl) Levels on Germination of Common Chickweed Seeds

Consistent with the water potential experiment, no significant interaction was observed between the two experimental repetitions and the salinity treatments, indicating that the effect of salinity on germination percentage of common chickweed seeds was consistent across both experiments. Therefore, the data for the two experiments were combined and reanalyzed. The germination of common chickweed seeds decreased as salinity increased beyond 5 dS m^{-1} (Figure 3). Germination at electrical conductivity (EC) levels of 0, 2.5, and 5 dS m^{-1} was similar and ranged from 95 to 97%. As the EC levels increased beyond 5 dS m^{-1} , germination sharply declined, reaching complete inhibition at 25 dS m^{-1} . The nonlinear three-parameter sigmoidal regression equation estimated that the EC level at which germination of common chickweed seeds decreased by 50% was 14.5 dS m^{-1} .

3.3. Effects of pH Levels on Germination of Common Chickweed Seeds

Similar to the water potential and salinity experiments, the effects of the pH treatments on common chickweed germination were consistent across both experimental repetitions with no significant interactions. Therefore, data from the two experiments were combined and reanalyzed. Although the seeds from the same collection locations as the other studies were used, in general, germination at all the pH levels was lower than that in the water potential and salinity studies for reasons that could not be verified within the scope of this study. The highest germination occurred at pH 7 but it was only 43%. Germination of common chickweed seeds was greater under neutral pH levels than under both alkaline and acidic levels (Figure 4). Relative to the pH 7 treatment, the seed germination percentage was reduced by approximately 22% at pH 8 (34% approximately). A severe reduction in germination was observed at pH 9 with only 3% of the seeds germinating, whereas no germination occurred at pH 5.

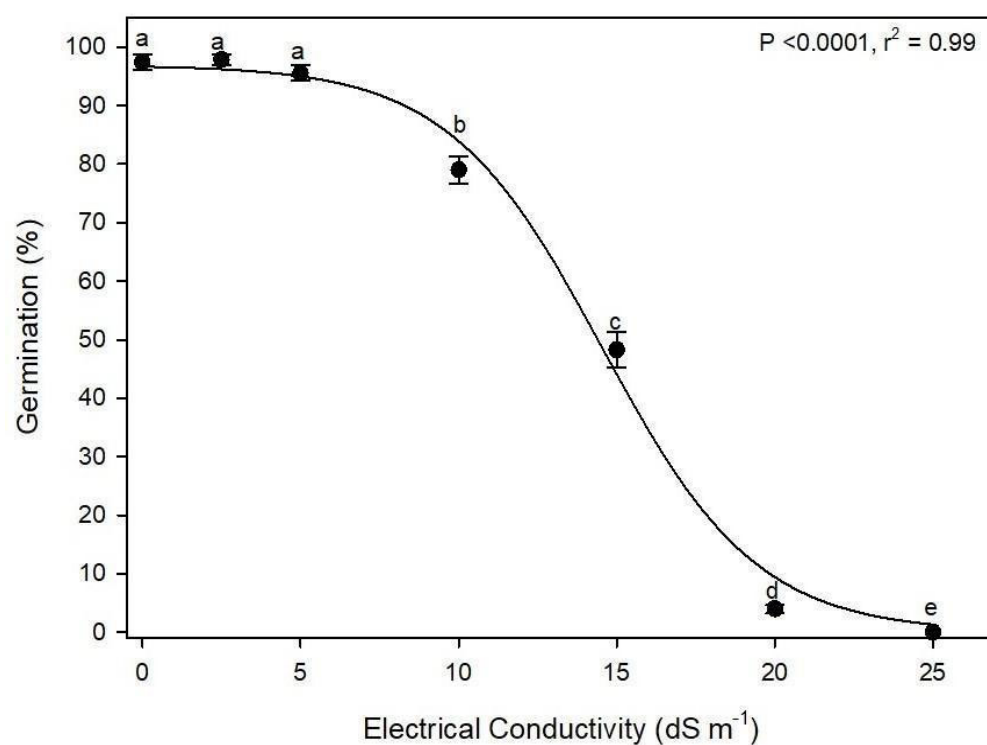


Figure 3. Percent germination (mean $\pm$ SEM) of common chickweed seeds in response to various levels of salinity (electrical conductivity in dS m^{-1}) simulated by sodium chloride concentrations. The means for the treatments with different letters indicate significant difference according to Fisher's Least Significant Difference test at $\alpha = 0.05$. The solid curve represents the fitted three-parameter nonlinear sigmoidal regression model.

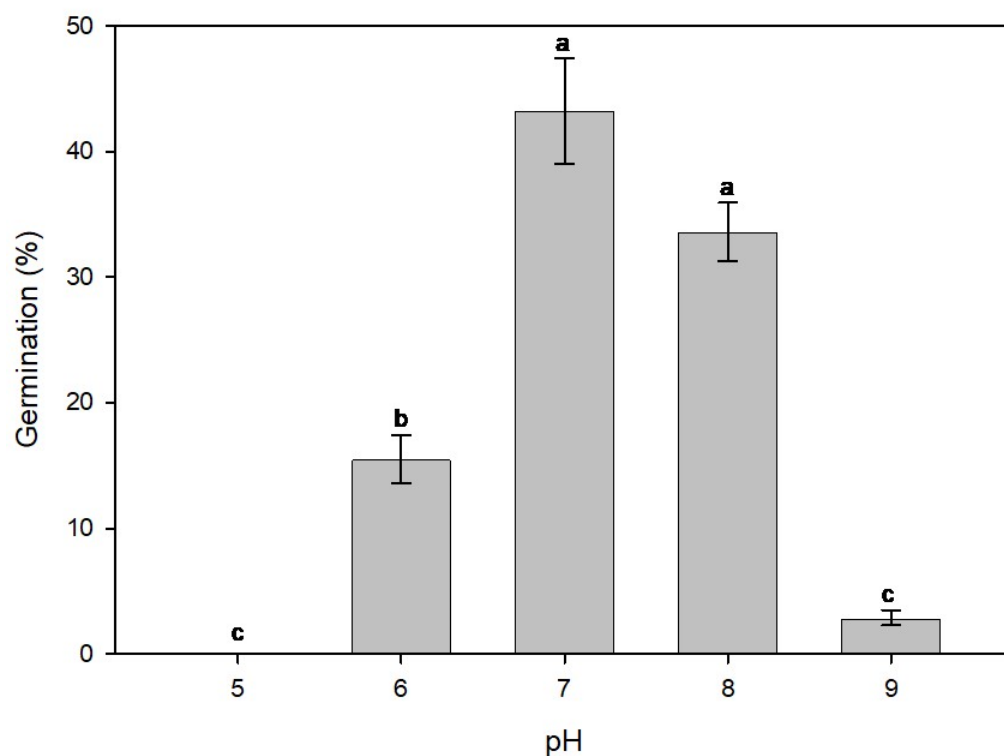


Figure 4. Germination percentage (mean $\pm$ SEM) of common chickweed seeds under different pH levels. The bars with different letters indicate significant difference according to Fisher's Least Significant Difference test at $\alpha = 0.05$.

3.4. Effect of Common Chickweed Infestations on Yield, Height, and Spike Length of Forage Wheat

There was a significant interaction between year and treatment on the competitive effect of common chickweed on the fresh-weight yield of forage wheat. Therefore, the fresh-weight data were analyzed separately for each year, whereas dry biomass data were combined for the two years because of lack of interaction between year and treatment. The effect of block (location) was not significant ($p > 0.05$), indicating the results were consistent among locations. The interaction in fresh weight may have been caused by differences in moisture levels in the infested and non-infested plots in the two years. The average moisture level in the samples from the infested plots and non-infested plots was 60.7 and 76.3% respectively in 2024, whereas it was 75.5 and 73.7% respectively in 2025. In both years, the wheat in the plots infested with common chickweed had lower fresh weight than those in the non-infested plots (Figure 5). However, the magnitude of the difference between the infested and non-infested plots was higher in 2024 than 2025. In 2024, infested areas had a 44.2% reduction in fresh weight, while in 2025 the reduction was 22.1%, showing that presence of common chickweed may significantly suppress wheat fresh biomass production. The difference in the magnitude of fresh biomass may be related to the differing levels of infestation of common chickweed and moisture content in the plants between 2024 and 2025. In 2024, the fresh biomass of common chickweed on a square meter area basis was $335.6 \pm 28.4 \text{ g m}^{-2}$, whereas in 2025 it was $144.8 \pm 20.4 \text{ g m}^{-2}$.

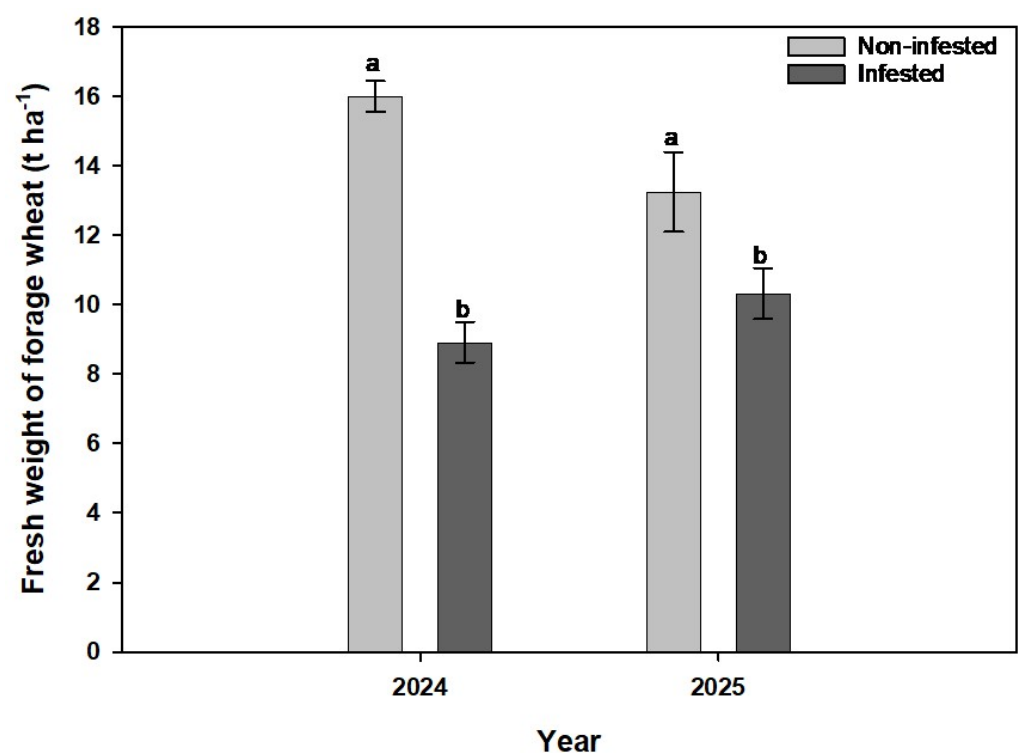


Figure 5. Effect of the presence and absence of common chickweed on the fresh biomass of forage wheat at the soft dough stage in the 2024 and 2025 growing seasons. For each year, the bars with different letters indicate significant difference according to the Cochran–Mantel–Haenszel Statistics (based on rank scores) test at $\alpha = 0.05$.

Unlike fresh weight, there was no interaction ($p > 0.05$) between the year and treatment for dry matter biomass; therefore, the data were combined for the two years and analyzed. Again, the effect of block (location) was not significant ($p > 0.05$), indicating the results were consistent among locations. Similar to fresh weight, dry matter biomass was approximately 12% lower in the wheat from the infested plots compared to those from the non-infested

plots ($p = 0.010$). The wheat from the non-infested plots had an average mean dry matter production of $13.90 \pm 0.45 \text{ t ha}^{-1}$ compared to $12.35 \pm 0.65 \text{ t ha}^{-1}$ in the infested plots, indicating that chickweed infestation also reduced dry matter.

The effect of common chickweed on the stature of the wheat plants was assessed by measuring the entire wheat stem length (plant height) and length of the spike alone in both the infested and non-infested plots. There was no significant year-by-treatment interaction ($p > 0.05$) for these variables. Therefore, data from both years for these two variables were combined and analyzed. The height of the wheat plants in the infested plots was reduced by 9.06% compared to those plants in the non-infested plots, thus indicating common chickweed's negative impact on wheat height. The height of the wheat plants was $109.30 \pm 2.86 \text{ cm}$ and $99.40 \pm 1.20 \text{ cm}$ in the non-infested and infested plots, respectively. However, the spike length was not affected by common chickweed infestations. The spike length was $11.2 \pm 0.3 \text{ cm}$ and $10.8 \pm 0.1 \text{ cm}$ in the infested and non-infested plots, respectively.

Crop plant population counts in weedy and weed-free plots also help in assessment of crop–weed competition in the form of stand loss [22]. Wheat stand count assessment in this current study showed a significant year-by-treatment interaction. Therefore, data were analyzed separately for each year. Wheat stand count was decreased by common chickweed infestations in both years of the study. In 2024 the mean density of the wheat plants in the non-infested and infested plots was 491 and 275 plants m^{-2} , respectively, a 44% reduction in wheat stand. In 2025, density of the wheat plants was 473 and 345 plants m^{-2} in the non-infested and infested plots, respectively. This reduction was 27%.

3.5. Effect of Common Chickweed Infestations on Selected Nutritive Components of Forage Wheat

The forage quality parameters (crude protein, acid detergent fiber, neutral detergent fiber, starch, and ash) of the wheat and common chickweed plants were inconsistent between the two years. Therefore, data for the two years were analyzed separately. However, the effect of block (location) was not significant ($p > 0.05$), indicating that the results were consistent among locations. In both years of the study, the mixed sample of wheat and common chickweed from the infested plots had higher amounts of the nutritive components compared to the non-infested wheat-only samples, particularly in crude protein (CP) and digestive parameters (Table 1). The wheat-alone samples had lower CP in both years compared to the wheat-alone samples from the infested plots and the mixed (wheat and common chickweed together) treatments. Therefore, the presence of common chickweed contributed to higher CP concentration in the infested and in the mixed treatments in both years. The acid detergent fiber (ADF) and neutral detergent fiber (NDF) values were the highest in the wheat samples from the non-infested plots in both years of the study (Table 1). Common chickweed infested samples had lower ADF and NDF concentrations and the values for these parameters were the lowest in the mixed sample of wheat and the weed. In both years, the starch content showed variable responses: it was higher overall in the samples of wheat from the non-infested plots than those from the infested plots and the mixture of wheat and common chickweed in 2024, but the reverse was true in 2025 (Table 1). The ash content tended to be lower in the wheat samples from the infested plots compared to that in the other samples in 2024, but in 2025 the ash content was similar in the wheat samples from both the infested and non-infested plots (Table 1). The chickweed alone had 13.62% CP and the other quality parameters were comparable to wheat (although statistical comparisons cannot be made), as seen in Table 1.

Table 1. Forage quality (percent crude protein, acid detergent fiber, neutral detergent fiber, starch, and ash) of wheat in the plots with and without common chickweed.

Treatment	CP %		ADF %		NDF %		Starch%		Ash%	
	2024	2025	2024	2025	2024	2025	2024	2025	2024	2025
Non-Infested	7.9 c	7.1 b	38.2 a	36.4 a	57.5 a	55.0 a	16.9 a	21.1 b	7.2 a	5.2 b
Infested	8.7 b	7.4 b	37.1 b	33.3 b	56.3 a	51.2 b	13.2 b	25.4 a	6.8 b	5.5 b
Mixed	10.3 a	8.2 a	36.1 c	33.0 b	52.7 b	50.7 b	13.5 b	24.9 a	7.4 a	5.9 a
Common Chickweed	13.6		35.0		46.02		14.6		7.7	

Note: Means of 2024–2025 forage quality analysis parameters (crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), starch, and ash) are for wheat sampled at the soft dough stage. Means within a column followed by the same letter are not significantly different according to Fisher's Least Significantly Different test at the 0.05 level of significance. Common chickweed-alone values are included for comparison purposes only. n = 20 in 2024 and 10 in 2025 for all the treatments. The analysis and mean separation were conducted on square-root-transformed data but non-transformed means are reported for ease in interpretations.

4. Discussion

4.1. Germination of Common Chickweed Seeds Under Varying Water Potential, Salinity, and pH Levels in the Laboratory

The decline in germination of common chickweed seeds at the highest water potential (−0.07 MPa) indicated that this species is very sensitive to osmotic stress conditions at germination. Studies have reported that, under drought conditions, common chickweed exhibits a drought-avoidance germination strategy rather than drought tolerance [23–26]. Although common chickweed is reported to have a broad geographic distribution and colonizes various regions [7], most of the studies on the germination ecology of common chickweed under drought (osmotic stress) have been conducted by Grundy and colleagues. These studies included the effects of temperature and Ψ and were explained by hydrothermal time germination models of common chickweed [23–25]. Similar to the present study, it was reported that germination percentage declined as the water potential decreased [23]. Furthermore, the study reported that the germination of all seven sampled seed populations of common chickweed ceased at −1.14 MPa under constant-temperature regimes. In a subsequent study using the hydrothermal time model [24], germination of common chickweed at 1.0 MPa was nearly completely inhibited, further indicating that germination of this species is limited at lower water potentials. Laboratory findings were later validated in a field study [25]. Under dry conditions, common chickweed seed emergence was suppressed more quickly than that of common lambsquarters (*Chenopodium album* L.), further confirming that common chickweed has low drought tolerance. It was further reported in a study of 11 common weed species exposed to extreme water stress that common chickweed was the first among them to wilt [7].

A base water potential for common chickweed has not been established in the studies of Grundy [23–25], or this present study due to the variability and plasticity of different populations of this species. Common chickweed populations may have their own base Ψ and base temperature thresholds. This is probably the reason why common chickweed is capable of emerging in flushes, which has allowed this opportunistic weed to be seen germinating all year round in certain regions. It was observed that older common chickweed seed lots had higher germination percentages than fresh seed lots (i.e., seed dormancy decreased with storage), but under severe water stress, seed age did not affect dormancy [23]. It was concluded that under severe drought conditions, dormancy will be triggered in common chickweed seed populations, but some populations can germinate at a reduced rate outside their optimum temperature and water potential conditions ranges [24,25]. This conclusion helps explain the low levels of germination under drought conditions as simulated by osmotic stress in this present study.

The creation of drought conditions simulated by the water potential solutions during germination alone may not fully depict a species' ability to germinate and continue growing under dry conditions in the field. However, it provides valuable insight into the potential spread of common chickweed occurrences, especially in arid conditions [24]. In the present study a low level of osmotic stress tolerance was observed in seeds of common chickweed plants growing in the SJV. It can be concluded that common chickweed prefers areas with constant moisture but has some potential to germinate in semi-arid regions. This explains this species' presence in the irrigated cropping systems of these regions during the cooler seasons of the year.

Although there are no published reports on the germination of common chickweed seeds under different salinity levels, there are reports on other ecologically similar weeds with an annual life cycle, using similar methods to this study. Also, there are general reports describing the effects of salinity on seed germination of glycophytes, plants that are salt-sensitive and cannot grow in high-salinity soils [27]. In this present study, the germination inhibition of common chickweed was dose-dependent with increasing salinity levels beyond 5 dS m^{-1} . Similarly, it was reported that germination of shepherd's purse (*Capsella bursa-pastoris*), a common winter annual in the SJV often observed in the same fields as common chickweed, decreased as salinity levels increased, with the lowest seed germination at electrical conductivity (EC) levels of 16 and 20 dS m^{-1} [28]. In summer annuals, complete inhibition of the germination of common lambsquarters and nettle-leaf goosefoot (*Chenopodium murale* L.) was observed beyond 20 dS m^{-1} , with 50% reduction in germination at approximately 14 dS m^{-1} in both species [29].

Glycophytic species, such as common chickweed, have limited salinity tolerance during germination. It has been reported that high salinity forces dormancy in seeds rather than adaptation [27]. A study concluded that salinity reduces seed germination through osmotic stress and ionic toxicity. These effects are exacerbated as EC levels increase [30]. The specific mechanism underlying reduced germination in saline conditions was also observed in another study [29]. This study did not measure that mechanism; therefore, osmotic stress and ionic toxicity can be suggested as possible contributing factors rather than confirmed causes of limiting germination as EC levels increased in this study. Since several of the seeds germinated at high EC levels, it can be suggested that common chickweed has the potential to germinate in the mild to moderate salinity soils that occur in various areas of the SJV. According to a study, salinity levels in the western SJV range from near 0 to about 35 dS m^{-1} , with about 50% of the soils having EC_e values below 8 dS m^{-1} [31]. However, it is not known whether the common chickweed seeds that germinated at the high EC levels have the potential to establish, grow, and complete their life cycle.

The literature review found no ecological studies that have assessed the germination of common chickweed seeds to various pH buffer solutions in controlled environments. Most previous studies have reported ecological observations of common chickweed with the conclusion that this species can adapt to a wide range of soil conditions [6,7,32] but it is not known to be the best colonizer and is highly sensitive to soils with a pH below 5.4 [32]. However, the same paper stated that it can germinate in slightly acidic soils with a pH of 5.9 or higher. The inhibited germination of common chickweed seeds at pH 5 and the 30% germination observed in this present study within the pH 6 treatment support the report of Mann [32] to some extent. Furthermore, it is important to note that although germination was observed at certain pH levels, common chickweed's tolerance to those pH levels may not necessarily mean optimal plant growth, as severe pH stress can limit early establishment [6,7]. Also, the high germination under neutral and slightly alkaline pH conditions suggests that it has the potential to grow and invade the SJV where the soil pH in the agricultural fields ranges from 6.77 to 7.49 [33].

4.2. Effect of Common Chickweed Infestation on Forage Wheat Yield, Plant Height, Spike Length, and Selected Nutritive Components of Forage Quality

Weeds, in general, reduce wheat yield, grain quality, and commercial value [34]. They compete with crops for light, water, and nutrients [35]. The amount of reduction may depend on the specific weed species. Common chickweed is a strong competitor in various cropping systems. For example, it has been reported that common chickweed reduced barley yields by 66–80% [36]. Similarly, it was reported that this weed species can cause 5% yield loss in oilseed rape (*Brassica* sp.) depending on weed densities [14].

Plant height and crop stand population are key variables in weed–crop competition studies for estimating yield. Plant height is easy to measure and can be used to model yield impacts [22]. The literature on the effect of common chickweed on the height of crops is limited, but other similar weeds have been reported to exhibit comparable impacts. For example, it was reported that wheat growing with *Viola arvensis* Murray was significantly shorter (46 cm) than weed-free wheat (64.1 cm), a 28% reduction. Furthermore, growth modeling in that study confirmed that the presence of the weed species limited wheat growth potential [22]. The reduction in the final height of the wheat plants in this current study was not as high, perhaps because of the different competitive abilities of the respective weed species.

The difference in the population of wheat plants in the two years may be because the exact location within the fields sampled in the two years were different and it is not known what the exact seeding rate of wheat in these fields were. It should be emphasized that this was not a controlled study with a certain experimental design. Rather, it was an observational study in grower fields with similar management practices. The fields had areas with common chickweed infestations and areas with no infestations, thus allowing comparisons. Regardless, these results suggested the early infestation of common chickweed in wheat fields can result in considerable reduction in stand establishment, which can have a direct effect on wheat yield, in addition to competition for water, light, and nutrients, as seen in fresh and dry matter losses in this current study.

The common assumption that weeds reduce forage quality has been based largely on generalization rather than supported research [37]. The results of this study and several others [37–40] demonstrate that certain weed species can have good nutritive composition contributing to forage quality and can serve as livestock feed. To understand the effects of common chickweed on nutritive composition of forage wheat, we must also understand the nutritional values of this species. A study reported that common chickweed leaves were highly nutritious, with 29.5% CP, 39.0% carbohydrates, 9.7% fiber, and 3.8% ash [41]. Overall, this indicates that common chickweed leaves are nutrient-dense and highly digestible. These values are better than those values in the samples of this study. The difference may be due to the presence of common chickweed stems in this study and also the fact that the plants were senescing at the time of sampling. Similarly, a study reported that common chickweed had relatively low ADF levels (16–21%) and NDF levels (17–22%) compared with ryegrass (*Lolium* sp.), which showed substantially higher ADF and NDF values [38]. These lower ADF and NDF values suggest reduced lignification and, therefore, easier digestion of common chickweed. It was also noted that broadleaf species such as common chickweed are more palatable and more readily consumed by grazing animals than ryegrass, probably because of their softer structure and lower NDF content [38]. Other weed species such as dandelion (*Taraxacum officinale* Weber) [38], johnsongrass [*Sorghum halepense* (L.) Pers.] [39], common burdock (*Arctium minus* (Hill) Bernh.), common cocklebur (*Xanthium strumarium* L.), common ragweed (*Ambrosia artemisiifolia* L.), horsenettle (*Solanum carolinense* L.), lance-leaf ragweed (*Ambrosia bidentata* Michx.), large crabgrass (*Digitaria sanguinalis* L. Scop.), late boneset (*Eupatorium serotinum* Michx.), spiny amaranth (*Amaranthus spinosus* L.), vervain

species (*Verbena* spp.), and tall fescue (*Lolium arundinaceum* (Schreb.) Darbysh.) have also been shown to offer higher or similar nutritional values to those of the desirable forage species [37–40]. However, certain weed species have been shown to be toxic or unpalatable to certain livestock [42], and the life cycle stage at harvest can also impact the nutritional value of weed species [38].

5. Conclusions

This study showed that the seeds of common chickweed were highly sensitive to osmotic stress and moderately sensitive to salinity. In addition, germination was higher under neutral pH conditions. These results from laboratory studies suggest that although common chickweed can germinate under some stress conditions, its establishment and spread are most likely going to be in areas with adequate moisture, low-to-moderate salinity, and neutral-to-slightly alkaline soils, such as those found in irrigated cropping systems of the SJV. Future studies should be geared towards understanding how common chickweed is able to grow and reproduce under varying environmental stresses, as adaptation could expand its potential range in SJV and similar regions under field conditions.

This study also showed that forage wheat fresh and dry biomass and plant height were lower in areas with common chickweed infestations. As such, this could lead to economic losses. However, the presence of common chickweed in the fields did not reduce the measured nutritive components of forage wheat. Therefore, it might be considered a supplementary forage, provided it does not have other negative parameters not tested in this study. Thus, the findings of this study could potentially lead to a shift in the perception of common chickweed infestations in forage wheat fields, and growers may have to consider the pros and cons of management actions for common chickweed infestations. However, controlled field studies may have to be conducted to verify the findings of this study.

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