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Salinity Stress: Comparative Effects of Sodium and Potassium Salts on Chickpea (*Cicer arietinum* L.) Germination and Vigor

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ABSTRACT

Background: Salt stress is a significant environmental factor that affects plant growth and productivity, particularly in regions with increasing soil salinization. Understanding the impact of different salt types and concentrations on seed germination and seedling vigor is crucial for developing strategies to mitigate salinity stress in agricultural settings. This study evaluates the effects of NaCl and KCl at varying concentrations on the germination and seedling vigor of the Goksu chickpea cultivar (*Cicer arietinum* L.).

Methods: The study was conducted at Gaziantep University, Nurdagi Vocational School between November 2022 and January 2023. This study evaluates the effects of different salt types (NaCl and KCl) and their varying concentrations on the germination and seedling vigor of the Goksu chickpea cultivar. The experiment was conducted under controlled conditions with seven different concentrations of each salt (0, 25, 50, 75, 100, 125 and 150 mm).

Result: It is indicated that increasing salt concentrations had a negative impact on all measured parameters. GP decreased significantly with higher salt levels, with NaCl treatments generally exhibiting higher GP compared to KCl. The MGT increased with higher salt concentrations, reflecting the delayed germination process under salinity stress. Both radicle and PL were adversely affected, with NaCl having a more pronounced negative impact compared to KCl. The GI, CVG and SVI also decreased significantly with higher salt concentrations, demonstrating the overall decline in seedling vigor under salinity stress.

Key words: Chickpea, Germination, KCl, NaCl, Salinity, Seed vigor, Stress tolerance.

INTRODUCTION

Belonging to the Fabaceae family, chickpea (*Cicer arietinum* L.) is a crucial crop widely recognized for its high protein content and essential nutrients, making it a vital component of human and animal diets (Jukanti *et al.,* 2012). Globally, chickpea ranks as the fourth most important legume crop after soybean, peanut and beans (Kapoor *et al.,* 2010; Cokkizgin, 2012a).

Apart from its nutritional value, chickpea is also significant due to its high content of carbohydrates, proteins, vitamins and minerals, essential for human health (Kaur and Prasad, 2021). Its high biological value, protein digestibility and protein efficiency ratio distinguish chickpea from other legumes, making it a superior choice in dietary planning (Kaur and Prasad, 2021).

Chickpea cultivation faces several challenges, especially environmental stressors like salinity, which can significantly hamper plant growth and yield (Haileselasie and Teferii, 2012). Salinity stress is known to affect various physiological processes in plants, including germination, growth and yield. Studies have shown that salt stress can reduce the number of pods per plant, filled pod numbers, seed numbers and seed yield in chickpea (Zamani *et al.,* 2017). Salinity also affects nodulation in chickpea, thereby impacting nitrogen fixation and overall plant health (Haileselasie and Teferii, 2012). As is well known, heavy metals have numerous adverse effects on living organisms. Similarly, salt exhibits negative impacts akin to those of heavy metals (Olgunoglu *et al.,* 2015; Olgunoglu and Olgunoglu, 2016).

Salinity, a major environmental stressor, has been the focus of extensive research (Purbajanti and Kusmiyati, 2024; Hamza *et al.,* 2023; Mariyappillai and Kulanthaivel, 2024; Sinky *et al.,* 2024). Studies have explored chickpeas physiological and biochemical responses to salinity stress. For instance, salicylic acid induces changes that may mitigate some negative effects (Asadi *et al.,* 2013). Another study highlighted the role of silicon in enhancing chickpea growth and yield under saline conditions (Zamani *et al.,* 2017). These findings underscore the importance of exploring various treatments and interventions to improve chickpea resilience to salinity (Jha *et al.*, 2014; Dudhe and Kumar, 2018; Kaur *et al.,* 2022).

In this context, the present study aims to evaluate the effects of NaCl and KCl at different concentrations on the germination and vigor index of the Goksu chickpea cultivar.

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MATERIALS AND METHODS

The study used Goksu chickpea seeds (*Cicer arietinum* L.), selected for uniformity in size, color and weight. Conducted at Gaziantep University Nurdagi Vocational School (Turkey) between November 2022 and January 2023, the experiment employed a completely randomized design with three replications. Each replication included 20 seeds in Petri dishes. Seven doses of NaCl and KCl (0, 25, 50, 75, 100, 125 and 150 mm) were tested. Seeds were treated under controlled conditions (20°C) in an incubator with a 12-hour light/dark cycle.

Before germination, chickpea seeds were sterilized using a 5% sodium hypochlorite solution for 10 minutes to prevent any fungal or bacterial contamination, followed by thorough rinsing with distilled water to remove any residual sterilizing agent. This step was crucial to eliminate any potential sources of infection that could affect the germination process.

Seeds were placed on double-layered moistened filter paper within the Petri dishes to ensure consistent moisture availability. The Petri dishes were sealed with parafilm to maintain humidity levels and prevent water loss. The seeds were incubated at 20°C for 9 days, a temperature identified as optimal for chickpea germination. Germination was monitored daily and abnormal or ungerminated seeds were identified and recorded following the rules of the International Seed Testing Association (ISTA, 2011).

Parameters Evaluated

Germination rate (GR) (%)

It was assessed daily and the germination percentage was calculated using the formula: (AOSA, 1990).

Germination percentage =

$$\frac{\text{Number of germinated seeds}}{\text{Total number of seeds}} \times 100$$

Mean germination time (MGT) (days)

It was determined according to Ellis and Roberts (1981) using the formula:

$$\text{Mean germination time} = \frac{\sum (n \times d)}{\sum n}$$

Where,

n= Number of seeds germinated on day d.

Radicle and plumule length (RL and PL)

The length of the radicle (root) and plumule (shoot) was measured using a digital caliper for all germinated seeds (Cokkizgin and Colkesen, 2012; Cokkizgin, 2012b; Girgel *et al.,* 2019).

Germination index (GI)

This index provides a measure of the speed and uniformity of germination. It was calculated according to AOSA (1990) rules using the formula:

Germination index =

$$\sum \frac{\text{Number of germinated seeds on day i}}{\text{Day i}}$$

Coefficient of velocity of germination (CVG)

This coefficient provides an indication of the speed of germination. It was calculated using Maguire's (1962) formula:

$$\text{Coefficient of velocity of germination} = \frac{\sum n}{\sum n \times d}$$

Seed vigor index (SVI)

It was calculated using the formula by Baki and Anderson (1973):

$$\text{SVI} = \text{GP} \times (\text{Radicle length} + \text{Plumule length})$$

The experimental data were subjected to analysis of variance (ANOVA) using SAS software to determine the significance of the treatment effects. The LSD (Least Significant Difference) test was used to identify differences between means at the 1% significance level, ensuring that even subtle differences were accurately detected (Duzgunes *et al.,* 1987). Additionally, the coefficient of variation was calculated to assess the degree of variation within the data, providing an indication of the reliability and precision of the experimental results.

RESULTS AND DISCUSSION

Germination percentage (%)

The ANOVA for germination percentage showed significant differences among salt types and concentrations. NaCl had a higher germination percentage (89.762%) compared to KCl (78.010%), suggesting KCl's more detrimental effect on chickpea germination. This aligns with previous studies (Yildirim, 2020). Mann *et al.* (2019) also reported that salinity affects germination percentage. These findings support that increasing salt concentrations negatively impact germination. The reduction is due to osmotic stress and ion toxicity, inhibiting water uptake and disrupting metabolic processes essential for germination (Ludwiczak *et al.,* 2021).

The higher germination percentage with NaCl compared to KCl suggests chickpea seeds respond differently to these salts due to their distinct ionic compositions affecting membrane stability and enzyme activity (Hasegawa *et al.,* 2000; Zhu, 2002). This aligns with Dadasoglu *et al.* (2020), who found that chickpea seeds tolerate sodium chloride better than potassium chloride. This differential response underscores the importance of understanding specific salt effects on germination and the need for targeted strategies to mitigate salinity impacts on crop production.

Mean germination time (days)

The mean germination time (MGT) increased with higher salt concentrations, with the longest time observed at 150 mM

(7.395 days) and the shortest at 0 mM and 25 mM (6.695 and 6.788 days, respectively) (Table 1-3). This suggests that higher salt concentrations delay the germination process due to osmotic stress and ion toxicity inhibiting water uptake and metabolic activities essential for germination (Zhu, 2002).

These findings are consistent with the observations made by Dadasoglu *et al.* (2020), who reported increased mean germination time in chickpeas under salinity stress. The significant increase in MGT at higher salt concentrations is consistent with findings from previous studies that show salinity stress delays germination (Ruan *et al.,* 2002; Kaya *et al.,* 2006). The delay in germination at higher salt concentrations can be attributed to the reduced water potential, which hampers seed imbibition and delays the initiation of metabolic processes necessary for germination (Hasegawa *et al.,* 2000).

Higher mean germination time in KCl treatments compared to NaCl treatments highlights their differential impact on chickpea germination, as observed by Dadasoglu *et al.* (2020). This is due to distinct ionic effects of potassium and sodium on cellular processes and membrane stability (Zhu, 2002). NaCl delays germination more than KCl due to its higher osmotic potential (Rahnama *et al.,* 2010).

Seed priming techniques have been shown to mitigate the effects of salinity stress on MGT. Studies by Khajeh-Hosseini *et al.* (2003) and Afzal *et al.* (2008) highlight the role of seed priming in enhancing seed metabolic activity and reducing the delay in germination caused by salinity. Additionally, maintaining optimal environmental conditions, such as soil moisture and temperature, can alleviate the negative effects of salinity on MGT (Ruan *et al.,* 2002).

Plumule length (cm)

The analysis of variance (ANOVA) for plumule length showed significant differences among the salt concentrations but not between the salt types (Tables 1-3). The plumule length decreased with increasing salt concentrations. The longest plumule length was observed at 0 mm (4.2 cm) and the shortest at 150 mm (2.83 cm), demonstrating the negative impact of salts on plumule growth.

The reduction in plumule length with increasing salt concentrations is consistent with previous studies, indicating that salt stress inhibits shoot growth in chickpeas. This phenomenon can be attributed to osmotic stress and ion toxicity, which disrupts water uptake and cellular functions necessary for growth (Zhu, 2002).

Ahmed *et al.* (2023) emphasize seed priming techniques to mitigate salinity effects on seedlings, enhancing crop resilience and performance. Buyukyildiz *et al.* (2023) and Dogan and Carpici (2016) highlight the crucial roles of light, moisture and temperature in plumule development during germination. Adequate moisture activates growth processes, while light triggers hormonal responses for elongation and leaf development. Suboptimal conditions like insufficient light or poor soil quality can hinder plumule development, impacting seedling health and viability.

Radicle length (cm)

The analysis of variance (ANOVA) for radicle length indicated significant differences among the salt concentrations, but not between the salt types (Table 1-3). Radicle length decreased as salt concentration increased. The longest radicle length was observed at 0 mM (5.45 cm),

Table 1: ANOVA summary for all parameters.

		Means of square						
Source of variation	f	GP	MGT	PL	RL	GI	CVG	SVI
Salt type	1	1450.243**	0.1429*	0.3438	0.4821	56.0291**	0.000053*	112199.3**
Salt dose	6	524.414**	0.3159**	1.5199**	1.8788*	55.1080**	0.000127**	169062.7**
Salt type × Salt dose	6	75.441	0.0162	0.1910	0.0888	5.1239*	0.000006	2015.2
Error	28	59.589	0.0206	0.3180	0.7333	1.7494	0.000008	11593.8
Total	41							
CV%		9.2023	2.0513	16.0705	17.6220	11.6833	1.9803	15.1934

*,** Significant at 0.05 and 0.01 probability levels, respectively.

Table 2: Means of all parameters and statistical groups for KCl and NaCl.

Salt	GP (%)	MGT	PL (cm)	RL (cm)	GI	CVG	SVI
KCl	78.010b	7.070a	3.600	4.752	10.166b	0.1417b	657.00b
NaCl	89.762a	6.953b	3.419	4.967	12.476a	0.1440a	760.38a
Mean	83.886	7.011	3.510	4.860	11.321	0.1428	708.69

Means followed by the same letter are not significantly different at p<0.05 level (LSD test).

while the shortest was at 150 mm (4.05 cm), showcasing the adverse effects of salinity on root growth. Similary Mann *et al.* (2019) reported that root length was affected by salinity.

These findings align with previous research that demonstrates a negative correlation between salinity and root growth (Akin, 2018). Osmotic stress and ion toxicity are primary factors that contribute to reduced water uptake and cellular damage, leading to shorter radicle lengths (Hasegawa *et al.,* 2000).

Germination index

The analysis of variance (ANOVA) for germination index indicated significant differences among the salt concentrations and between the salt types (Table 1-3). The germination index decreased with increasing salt concentrations, highlighting the negative impact of salinity on the vigor and speed of germination.

The significant reduction in germination index at higher salt concentrations is in line with the findings of Akin (2018) and similar studies that reported analogous trends in various crops. Salinity stress influences seed germination by altering enzyme activity, disrupting cellular structure and causing oxidative damage, which collectively lead to decreased vigor and slower germination rates (Kaya *et al.,* 2006).

Additionally, environmental factors such as light and temperature play critical roles in modulating germination and seedling growth (Jisha *et al.,* 2013). Optimal conditions can mitigate the negative effects of salinity, improving germination index and overall seedling vigor.

Coefficient of velocity of germination

The analysis of variance (ANOVA) for the coefficient of velocity of germination (CVG) indicated significant differences among the salt concentrations and between the salt types (Table 1-3). The CVG decreased with increasing salt concentrations, indicating that higher salinity slows down the germination process.

The significant reduction in CVG at higher salt concentrations aligns with the findings of Akin (2018) and similar studies. Higher salinity levels cause osmotic stress and ionic imbalance, which delay the germination process and reduce the speed of seedling emergence (Ludwiczak *et al.,* 2021). Research by Kaya *et al.* (2006) highlights that the osmotic potential of the external medium and ion toxicity are critical factors influencing CVG. Studies have shown that NaCl and KCl have differential impacts on germination, with NaCl generally having a more pronounced effect on slowing down germination rates compared to KCl (Rahnama *et al.,* 2010).

Ahmed *et al.* (2023) emphasize the role of seed priming techniques in improving the CVG under saline conditions. Seed priming can activate various physiological and biochemical processes in seeds, making them more resilient to salinity stress. Additionally, research by Khajeh-Hosseini *et al.* (2003) suggests that pre-sowing treatments can mitigate the adverse effects of salinity on CVG, enhancing germination rates and seedling vigor.

Genetic improvement and breeding for salinity tolerance can enhance the CVG in chickpeas (Atieno *et al.,* 2021). Understanding the genetic basis of salinity tolerance can aid in developing more resilient crop varieties, which is crucial for improving crop establishment and yield in saline environments.

Seed vigor index

The analysis of variance (ANOVA) for the seed vigor index (SVI) revealed significant differences among the salt concentrations and between the salt types (Table 1-3). The SVI decreased as salt concentration increased, indicating that higher salinity negatively impacts seedling vigor and overall health.

The significant reduction in SVI at higher salt concentrations aligns with previous findings that salinity stress adversely affects seedling growth and vigor. Salinity-induced osmotic stress and ion toxicity disrupt cellular functions, leading to poor seedling development and reduced vigor (Kaya *et al.,* 2006; Ceritoglu and Erman, 2020).

Research by Khajeh-Hosseini *et al.* (2003) demonstrates that salt stress reduces seedling growth parameters, including root and shoot length, which are crucial components of the SVI. Moreover, pre-sowing treatments like seed priming can enhance seed vigor by improving the metabolic and physiological readiness of seeds to withstand salinity stress (Bewley *et al.* 2013). Studies by Ding *et al*., 2009 and Desheva *et al.,* 2024, highlight that

Table 3: Means of all parameters and statistical groups for various salt concentrations.

Salt dose	GP (%)	MGT (days)	PL (cm)	RL (cm)	G I	CVG	SVI
0	96.95a	6.695c	4.20a	5.45a	16.193a	0.1493a	936.55A
25	93.88ab	6.788c	3.98a	5.48a	14.453b	0.1473a	889.20AB
50	86.95bc	6.973b	3.6ab	5.23ab	11.538c	0.1435b	766.67BC
75	83.33cd	7.055b	3.70ab	4.88abc	10.378cd	0.1418b	715.92CD
100	78.88cde	7.038b	3.17bc	4.57abc	9.895d	0.1422b	603.78DE
125	75.53de	7.133b	3.07bc	4.35bc	9.243d	0.1403b	557.40E
150	71.67e	7.395a	2.83c	4.05c	7.543e	0.1353c	491.32E
Mean	83.886	7.011	3.510	4.860	11.321	0.1428	708.69

Means followed by the same letter are not significantly different at $p<0.05$ level (LSD test).

NaCl and KCl have differential effects on seedling growth, with NaCl generally having a more pronounced negative impact compared to KCl. This differential response can be attributed to the distinct ionic compositions and their specific interactions with cellular processes.

Genetic improvement and breeding for salinity tolerance can also enhance the SVI in chickpeas and other crops. Studies by Afzal *et al.* (2020), Shams and Khadivi (2023) emphasize the importance of understanding the genetic mechanisms underlying salinity tolerance to develop more resilient crop varieties. Enhancing seed vigor through genetic and agronomic approaches can significantly improve crop establishment and yield in saline environments.

CONCLUSION

This study analyzes the effects of different salt types (NaCl and KCl) and concentrations on the germination and seedling vigor of Goksu chickpea. The findings show that higher salt concentrations negatively impact all parameters, such as germination percentage, mean germination time (MGT), radicle length, plumule length, germination index, coefficient of velocity of germination (CVG) and seed vigor index (SVI).

Higher salt concentrations significantly reduce germination percentage, indicating that salinity stress hinders germination. NaCl treatments generally result in higher germination percentages compared to KCl. Mean germination time increases with higher salt concentrations, indicating delayed germination due to osmotic stress and ion toxicity.

Both radicle and plumule lengths are adversely affected by increasing salt concentrations, with NaCl showing a more pronounced negative effect on seedling growth than KCl. Germination index, CVG and SVI decrease with higher salt concentrations, indicating an overall decline in seedling vigor.

Strategies to mitigate salinity effects include seed priming and maintaining optimal environmental conditions. Genetic improvement and breeding for salinity tolerance are crucial for developing resilient crop varieties and enhancing germination and seedling growth in saline environments.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

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