

1 **Evaluation of salt stress tolerance in wheat varieties cultivated in the** 2 **polders of lake chad at the germination stage.**

3 **Abstract**

4 Soil salinity is one of the major abiotic stresses that severely limits agricultural productivity,
5 particularly in arid and semi-arid regions. This study evaluated the effects of salt stress on
6 germination and early seedling growth of five wheat varieties subjected to five sodium
7 chloride (NaCl) concentrations: 0, 75, 150, 225, and 300 mM. Key germination and growth
8 parameters, including germination percentage, germination speed index, root and shoot
9 length, and salt tolerance index, were measured. Analysis of variance revealed highly
10 significant differences ($p < 0.001$) among treatments for most variables. Mexipack and Soms
11 90 showed strong tolerance, maintaining relatively high germination and growth performance
12 even at elevated NaCl concentrations, while Marzak was highly sensitive, with substantial
13 reductions in germination and seedling growth at lower salt levels. These findings highlight
14 the critical importance of selecting wheat varieties adapted to saline conditions. They also
15 emphasize the strategic role of salt-tolerant genotypes in sustaining agricultural productivity
16 in the polders of Lake Chad, where soil salinization is progressively increasing. The results
17 provide valuable insights for breeding programs targeting salt tolerance and offer practical
18 guidance for improving the resilience of local wheat production systems under salinity stress.

19 **Keywords:** Salinity, NaCl, Germination, Lake Chad, Wheat, Tolerance, Abiotic Stress.

20

21

22 **Introduction**

23 Soil salinity is widely recognized as one of the major abiotic stresses that drastically limit
24 global agricultural productivity, particularly in arid and semi-arid regions (Farooq et al. 2024).
25 This phenomenon is primarily driven by the accumulation of sodium chloride (NaCl) in the
26 rhizosphere, often exacerbated by the use of irrigation water rich in dissolved salts. Excess
27 salinity imposes a dual constraint on plants, osmotic stress and ionic stress, negatively
28 affecting key physiological processes such as germination, seedling establishment, and overall
29 growth (Ilyess et al. 2013; Zhang et al. 2024). At the global scale, salinity and sodicity impact
30 approximately 1.38 billion hectares, representing 10.7% of the Earth's land surface (FAO

31 2024), with particularly devastating consequences in irrigated systems of the western Sahel,
32 where substantial yield losses are frequently reported (Thiam et al. 2021; Smaoui et al. 2024).

33 Wheat (*Triticum* spp.) is a staple cereal essential for global food security, cultivated on nearly
34 217 million hectares worldwide (Diakite et al. 2023). Despite its importance, wheat is
35 considered moderately sensitive to salinity, with vulnerability most pronounced during the
36 early developmental stages, notably germination and initial seedling growth (Rehman et al.
37 2025). The response of a given genotype to salt stress depends on both the applied salt
38 concentration and the phenological stage, making the assessment of early-stage tolerance
39 particularly critical (Ben Naceur et al. 2001). In the polders of Lake Chad, wheat plays a
40 significant agronomic and socio-economic role. However, its yield potential under optimal
41 management is increasingly compromised by progressive soil salinization. Although
42 historically fertile (Bouquet 1969), these areas are now confronted with salt accumulation
43 driven by irrigation without adequate drainage, capillary rise of saline groundwater, and
44 intense surface evaporation (Harter and Motis 2016). This process has led to reduced
45 cultivable land and declining yields, positioning salinization as the primary obstacle to
46 achieving the full productive potential of wheat in this region (Alladjaba et al. 2025). Given
47 the urgency of this situation, the identification and selection of salt-tolerant wheat varieties
48 represent the most effective and sustainable mitigation strategy to ensure the resilience of
49 local agricultural production (Wu et al. 2010; Khan and Gulzar 2003). The present study
50 therefore aims to evaluate the variability in the response of five wheat varieties to salt stress
51 induced by different NaCl concentrations. The main objective is to identify the most tolerant
52 genotypes based on their germination performance and early growth traits.

53 **Materials and Methods**

54 **Plant Material**

55 The experiments were conducted on five wheat (*Triticum* spp.) varieties (Table 1). Four of
56 these varieties are officially registered in the national catalogue of plant species and varieties
57 of Chad, while the fifth, Marzak, is an introduced variety that is widely cultivated and
58 disseminated in the Lake Province.

59 **Experimental Site**

60 The study was carried out under controlled laboratory conditions at the Support Unit of the
61 Chadian Institute of Agronomic Research for Development (ITRAD), located in Bol, Lake
62 Province. The experimental site is geographically positioned at 13°30'13.35" N latitude and
63 14°41'33.95" E longitude (Figure 1).

64 **Methods**

65 *Preparation of Salt Stress Solutions*

66 Salt stress solutions were prepared using analytical-grade sodium chloride (NaCl). The NaCl
67 was dissolved in sterile distilled water to obtain five distinct concentrations: 0 mM (control),
68 75 mM, 150 mM, 225 mM, and 300 mM. These concentrations were selected to simulate a
69 progressive gradient of salinity stress intensity.

70 *Experimental Design and Germination Conditions*

71 The experiment was conducted using a completely randomized design in Petri dishes. For
72 each wheat variety, twenty seeds were carefully rinsed with distilled water and uniformly
73 placed in 9 cm diameter Petri dishes. Salt treatments were applied by adding 5 mL of the
74 corresponding NaCl solution to each dish. After treatment application, the Petri dishes were
75 hermetically sealed to minimize evaporation and incubated in a growth chamber under
76 controlled environmental conditions with a 12 h light / 12 h dark photoperiod.

77 *Germination Monitoring*

78 Germination was monitored daily for seven consecutive days. The emergence of the radicle
79 through the seed coat was adopted as the criterion for germination. The number of germinated
80 seeds was recorded every 24 hours. To evaluate the effect of salinity stress on the performance
81 of the five wheat varieties, several parameters were assessed at the end of the experiment.

82 *Germination Parameters*

83 Germination Percentage (GP): Calculated as the percentage of germinated seeds at day i
84 (NG_i) relative to the total number of seeds sown (S):

$$85 \quad GP = (NG_i/S) \times 100 \quad (1)$$

86 Germination Speed Index (GSI): Determined according to Maguire (1962), reflecting the
87 rapidity and uniformity of germination. A higher GSI indicates faster germination:

88
$$\text{GSI} = \Sigma(\text{Gi}/\text{di}) \text{ (2)}$$

89 where G_i is the number of seeds germinated on day d_i .

90 ***Growth and Tolerance Parameters***

91 Radicle and Shoot Length (mm): Measured on seedlings at day 7 to assess inhibition of early
92 growth under salt stress. Salt Tolerance Index (STI, %): Based on the methodology of Slama
93 (1982), expressed as the relative performance of a variety under stress compared to its
94 performance under control conditions:

95
$$\text{STI} = (\text{X}_{\text{stress}}/\text{X}_{\text{control}}) \times 100 \text{ (3)}$$

96 STI was calculated for all germination and growth parameters, enabling classification of
97 varieties according to their physiological tolerance to salinity.

98 **Statistical Analyses**

99 Descriptive statistics, including mean, standard error (SE), minimum and maximum values,
100 and coefficient of variation (CV, %), were computed to characterize variability and
101 homogeneity of the data under different salinity levels. A one-way analysis of variance
102 (ANOVA) was performed to evaluate the main effects and interactions of salinity levels and
103 wheat varieties on all measured parameters. All statistical analyses and graphical
104 representations were conducted using R software.

105 **Results**

106 The analysis of variance (ANOVA) conducted to evaluate the effects of the factors Variety
107 and NaCl concentration revealed that Variety had a highly significant effect on the Salt
108 Tolerance Index (STI) ($p < 0.01$), and a very highly significant effect on both the Germination
109 Speed Index (GSI) ($p < 0.001$) and the Germination Percentage (GP) ($p < 0.001$). In contrast,
110 the effect of Variety was not significant for Shoot Growth (SG) and Root Growth (RG).

111 On the other hand, NaCl concentration exerted a very highly significant effect on all
112 parameters studied (SG, RG, STI, GSI, and GP) ($p < 0.001$), clearly indicating that increasing
113 salinity stress strongly inhibited seedling growth and negatively affected germination (Table
114 2).

115 ***Germination Percentage***

116 The analysis of germination data collected over a seven-day period revealed a progressive
117 reduction in Germination Percentage (GP) in response to increasing NaCl concentrations.
118 However, the magnitude of this inhibition was strongly genotype-dependent. The varieties
119 Mexipack and Soms 90 demonstrated resilience, maintaining relatively high germination
120 rates up to 150 mM NaCl. In contrast, Duilio and Marzak exhibited a sharp decline in
121 germination as early as 75 mM NaCl. These findings confirm the substantial genetic
122 variability among wheat varieties in their response to salinity stress at the germination stage
123 (Figure 2).

124 ***Root Growth***

125 Root growth of wheat seedlings exhibited a general and significant reduction correlated with
126 increasing NaCl concentrations, starting as early as 75 mM. Under control conditions (0 mM
127 NaCl), the variety Duilio, which initially developed roots of 13.1 cm, experienced a drastic
128 inhibition, dropping to 1 cm at 150 mM NaCl. In contrast, the varieties Soms 90 and
129 Mexipack, although showing moderate initial root growth, demonstrated the highest tolerance
130 by maintaining relatively stable root lengths of approximately 2 cm up to 225 mM NaCl,
131 indicating a superior ability to sustain root elongation under severe salinity stress. Conversely,
132 the varieties Marzak and Penjamo displayed very low average values and were strongly
133 affected even at the lowest salt concentrations tested (Figure 3).

134 ***Shoot Growth***

135 Shoot growth, measured as shoot length (SL), revealed an overall inhibitory trend similar to
136 that observed for root growth. The varieties Soms 90 and Duilio exhibited the greatest shoot
137 lengths under control conditions (8.1 cm and 8.2 cm, respectively), but both declined sharply
138 to less than 2 cm at 75 mM NaCl. Mexipack showed relative stability up to 150 mM NaCl,
139 although shoot growth remained weak beyond this concentration. The variety Penjamo
140 displayed a heterogeneous and irregular response. Finally, Marzak was distinguished by the
141 earliest and most severe inhibition, with shoot length drastically reduced to only 0.2 cm at 300
142 mM NaCl (Figure 4).

143 ***Germination Speed Index***

144 The Germination Speed Index (GSI), which quantifies the rapidity and uniformity of the
145 germination process, varied significantly among wheat varieties in response to salinity stress.
146 The varieties Mexipack and Penjamo stood out by maintaining relatively high and stable GSI

147 values up to 150 mM NaCl. The variety Soms 90 exhibited a moderate and slightly irregular
148 dynamic, with a slight decrease at 150 mM, followed by an unexpected increase at 300 mM
149 NaCl. In contrast, the varieties Marzak and Duilio consistently displayed low GSI values,
150 reflecting an intrinsically reduced germination speed and marked sensitivity regardless of the
151 applied salt concentration (Figure 5).

152 *Salt Tolerance Index*

153 The Salt Tolerance Index (STI) proved to be a key parameter in highlighting notable
154 differences among wheat varieties under varying NaCl concentrations. The varieties Soms
155 90 and Mexipack distinguished themselves by maintaining the highest mean STI values,
156 showing tolerance up to 150 mM NaCl. In contrast, the varieties Duilio and Marzak exhibited
157 a sharp decline, with STI values dropping below 50% as early as 225 mM NaCl (Figure 6).

158 **Discussion**

159 The results of this study unequivocally confirm that salinity exerts a significant inhibitory
160 effect on the processes of germination and early growth of wheat seedlings. The progressive
161 reduction in germination percentage, as well as in root and shoot length, observed with
162 increasing NaCl concentrations is in full agreement with the findings of Mahboob et al. 2023
163 and Wu et al. 2010. This inhibition is primarily attributed to the dual effect of salt stress: the
164 initial osmotic constraint, which hinders water uptake required for imbibition, and ionic
165 toxicity resulting from Na^+/K^+ imbalance, which disrupts enzymatic activity and early
166 physiological processes in wheat.

167 The study clearly highlights pronounced inter-varietal variability in response to salinity stress.
168 Among the five genotypes tested, Mexipack and Soms 90 emerged as the most tolerant,
169 maintaining high germination and growth performance up to 150 mM NaCl. This resilience
170 suggests that these varieties possess more efficient adaptive mechanisms, potentially
171 including enhanced osmoregulatory capacity, increased accumulation of compatible solutes
172 such as proline, and/or reinforced antioxidant activity to neutralize salt-induced oxidative
173 stress, as emphasized by Ibrahimova et al. 2025 and Mrani et al. 2013. Conversely, the variety
174 Marzak proved particularly sensitive, showing significant reductions in germination and
175 growth even at low NaCl concentrations. This sensitivity reflects a limited osmotic adjustment
176 capacity and heightened vulnerability, consistent with observations reported for salt-sensitive
177 genotypes (Zhang et al. 2024; El Sabagh et al. 2021).

178 The statistical analysis, which effectively distinguished tolerant from sensitive varieties,
179 validates the phenotypic approach employed in this study. The use of composite indicators
180 such as the Salt Tolerance Index (STI), combined with the analysis of morpho-physiological
181 traits, is widely recognized in the literature as a robust strategy for assessing and ranking
182 salinity tolerance (Dadshani et al. 2019; Ahmed et al. 2025). The variation observed in wheat
183 sensitivity across different NaCl concentrations further confirms the complex and polygenic
184 nature of salinity tolerance, as noted by Rehman et al. 2025.

185 In summary, this study confirms that salinity tolerance in wheat is an integrated trait governed
186 by a combination of physiological and genetic mechanisms. The varieties Mexipack and
187 Soms 90 are identified as promising genotypes and represent valuable genetic resources for
188 breeding programs aimed at improving wheat productivity in saline environments, particularly
189 in the polders of Lake Chad.

190 **Conclusion**

191 This study conclusively demonstrated that soil salinity exerts a significant inhibitory effect on
192 wheat seed germination and early seedling growth, with responses strongly differentiated
193 according to genotype. Increasing NaCl concentrations induced a progressive reduction in
194 germination percentage as well as in root and shoot length. Phenotypic screening results
195 allowed the classification of varieties according to their level of tolerance. The tolerant
196 varieties Mexipack and Soms 90 maintained satisfactory agronomic performance up to
197 concentrations exceeding 150 mM NaCl, whereas the sensitive variety Marzak exhibited high
198 vulnerability at concentrations below 150 mM NaCl. Statistical analyses confirmed the
199 robustness of these observations and suggest that germination vigor and root growth are
200 reliable indicators of early tolerance to salt stress. To better exploit this tolerance, further
201 research integrating advanced molecular and physiological approaches is recommended to
202 unravel the genetic bases and underlying mechanisms of salinity tolerance. Such insights will
203 guide future wheat breeding strategies aimed at improving productivity under increasing soil
204 salinization, particularly in vulnerable agroecosystems such as the Lake Chad polders.

205

206

207

208

209

210

211

212 **References**

213 Adoum, A. A., Blanca, Y., Le Martret, H. and Brossard, M. (2017). Pioneering assessment of
214 carbon stocks in polder soils developed in interdune landscapes in a semiarid climate, Lake
215 Chad. *Comptes Rendus Géoscience*, 349, 22–31.

216 Ahmed, K., Shabbir, G. and Ahmed, M. (2025). Exploring drought tolerance for germination
217 traits of diverse wheat genotypes. *BMC Plant Biology*, 25, 390.

218 Alladjaba, A., Andossa, L., Zakaria, M. N., Mahamat, A. M., Remadji, E., Altolna, M.,
219 Hamza, A. O. and Woli, B. (2025). Salinization and sodification of the Lake Chad polders:
220 Impact on agriculture and local management practices. *International Journal of Advanced*
221 *Research*, 13(6), 50–66.

222 Ben Naceur, M., Rahmoune, C., Sdiri, H., Meddahi, M. L. and Selmi, M. (2001). Effet du
223 stress salin sur la germination, la croissance et la production en grains de quelques variétés
224 maghrébines de blé. *Sécheresse*, 12(3), 167–174.

225 Bouquet, C. (1969). La culture du blé dans les polders du Lac Tchad. *Les Cahiers d’Outre-*
226 *Mer*, 22, 203–214.

227 Dadshani, S., Sharma, R. C., Baum, M., Ogbonnaya, F. C., Léon, J. and Ballvora, A. (2019).
228 Multi-dimensional evaluation of response to salt stress in wheat. *PLoS ONE*, 14(9),
229 e0222659.

230 Diakite, S., Pakina, E. N., Behzad, A., Zargar, M., Saquee, F. S., Kalabashkina, E. V.,
231 Tsymbalova, V. A. and Astarkhanova, T. S. (2023). Impacts of climate change, forms, and
232 excess of nitrogen fertilizers on the development of wheat fungal diseases. *Siberian Journal of*
233 *Life Sciences and Agriculture*, 15(2), 303–336. [https://doi.org/10.12731/2658-6649-2023-15-](https://doi.org/10.12731/2658-6649-2023-15-2-303-336)
234 [2-303-336](https://doi.org/10.12731/2658-6649-2023-15-2-303-336)

235 El Sabagh, M. S., Islam, M., Skalicky, M., Raza, K. A., Singh, M., Hossain, A. A., Hosain, W.,
236 Mahboob, M. A., Iqbal, D. and Ratnasekera, D. (2021). Salinity stress in wheat (*Triticum*

237 aestivum L.) under climate change: Adaptation and management strategies. *Frontiers in*
238 *Agronomy*, 3, 661932. <https://doi.org/10.3389/fagro.2021.661932>

239 Erenstein, O., Jaleta, M., Mottaleb, K. A., Sonder, K., Donovan, J. and Braun, H. J. (2022).
240 Global trends in wheat production, consumption and trade. In: Reynolds, M. P. and Braun, H.
241 J. (eds) *Wheat Improvement*. Cham: Springer, pp. 67–92. [https://doi.org/10.1007/978-3-030-](https://doi.org/10.1007/978-3-030-90673-3_4)
242 [90673-3_4](https://doi.org/10.1007/978-3-030-90673-3_4)

243 FAO (2024). *Global status of salt-affected soils*. Rome: Food and Agriculture Organization.

244 Farooq, M., Zahra, N., Ullah, A., Nadeem, F., Rehman, A., Kapoor, R., Al-Hinani, M. S. and
245 Siddique, K. H. M. (2024). Salt stress in wheat: Effects, tolerance mechanisms, and
246 management. *Journal of Soil Science*. <https://doi.org/10.1007/s42729-024-02104-1>

247 Harter, B. and Motis, T. (2016). *Understanding salt-affected soils*. ECHO Technical Note.
248 ECHOcommunity.

249 Ibrahimova, U., Talai, J., Hasan, M., Huseynova, I., Raja, V., Rastogi, A., Ghaffari, H.,
250 Zivcak, M., Yang, X. and Brestic, M. (2025). Dissecting the osmotic and oxidative stress
251 responses in salt-tolerant and salt-sensitive wheat genotypes. *Plant Soil and Environment*, 71,
252 36–47.

253 Ilyess, L., Louahlia, S., Laamarti, M. and Hammani, K. (2013). Effect of salinity stress on
254 germination and enzymatic activity in two *Medicago sativa* genotypes. *International Journal*
255 *of Innovation and Applied Studies*, 3(2), 511–516.

256 Khan, M. A. and Gulzar, S. (2003). Light, salinity, and temperature effects on the seed
257 germination of perennial grasses. *American Journal of Botany*, 90(1), 131–134.
258 <https://doi.org/10.3732/ajb.90.1.131>

259 Maguire, J. D. (1962). Speed of germination—Aid in selection and evaluation for seedling
260 emergence and vigor. *Crop Science*, 2(2), 176–177.

261 Mahboob, W., Rizwan, M., Irfan, M., Hafeez, O. B. A., Sarwar, N., Akhtar, M., Munir, M.,
262 Rani, R., El Sabagh, A. and Shimelis, H. (2023). Salinity tolerance in wheat: Responses,
263 mechanisms and adaptation approaches. *Applied Ecology and Environmental Research*, 21(6),
264 5299–5328.

265 Mehmet, A., Kaya, M. D. and Kaya, G. (2006). Effects of NaCl on the germination, seedling
266 growth and water uptake of triticale. *Turkish Journal of Agriculture*, 30, 39–47.

267 Mouaromba, W., Ngon, G. F. N., Adoum, A. A. and Bayiga, E. C. (2021). Impact of
268 agricultural practices on soil organic matter in polder soils: The case of Mamdi, Lake Chad.
269 *Revue Ivoirienne des Sciences et Technologie*, 38, 455–470.

270 Moussa, I., Walter, C., Michot, D., Boukary, I. A., Nicolas, H., Pichelin, P. and Guéro, Y.
271 (2020). Soil salinity assessment in irrigated paddy fields of the Niger Valley using a four-year
272 Sentinel-2 time series. *Remote Sensing*, 12(20), 3399. <https://doi.org/10.3390/rs12203399>

273 Mrani, A. M., El Jourmi, L., Ouarzane, A., Lazar, S., El Antri, S., Zahouily, M. and Hmyene,
274 A. (2013). Effect of salinity stress on germination and growth of six Moroccan wheat
275 varieties. *Journal of Materials and Environmental Science*, 4(6), 997–1004.

276 Rehman, S. U., Sarwar, N., Din, M. S. U., Shah, A. A., Iqbal, M. A. and Abbas, A. (2025).
277 Impact of soil salinity on wheat growth and yield: Challenges, mechanisms, and management
278 strategies. *Scholars Journal of Agriculture and Veterinary Sciences*, 12(2), 109–119.
279 <https://doi.org/10.36347/sjavs.2025.v12i02.003>

280 Slama, F. (1982). Effet du chlorure de sodium sur la croissance et la nutrition minérale: étude
281 comparative de six espèces cultivées. Thèse de doctorat, Université Tunis II, Faculté des
282 Sciences de Tunis.

283 Smaoui, J., Negacz, K. and van Tongeren, P. (2024). Salinity in African countries: From local
284 challenges to global solutions. IVM Report R-24/01. Amsterdam: Institute for Environmental
285 Studies, Vrije Universiteit Amsterdam.

286 Thiam, S., Villamor, G. B., Faye, L. C., Sène, J. H. B. and Diwediga, B. (2021). Monitoring
287 land use and soil salinity changes in coastal landscapes: A case study from Senegal.
288 *Environmental Monitoring and Assessment*, 193, 259. [https://doi.org/10.1007/s10661-021-](https://doi.org/10.1007/s10661-021-08958-7)
289 [08958-7](https://doi.org/10.1007/s10661-021-08958-7)

290 Wu, Y. B., Yan, Z. M., Wu, D. F., Chen, Z. C., Lv, W. Y. and Zhang, H. Y. (2010). Effect of
291 NaCl stress on seed germination and seedling growth in wheat. In *Proceedings of the 4th*
292 *International Conference on Bioinformatics and Biomedical Engineering (iCBBE 2010)*,
293 Chengdu, China, 10–12 June 2010, pp. 1–3.

294

295

296

297

298

299 **Table 1.**Wheatvarietiesstudied.

| Variety | Wheatspecies | Origin |
|----------|--|---------|
| Mexipack | Breadwheat (<i>Triticumaestivum</i>) | Mexico |
| Penjamo | Breadwheat (<i>Triticumaestivum</i>) | Mexico |
| Duilio | Durumwheat (<i>Triticumdurum</i>) | Italy |
| Somps 90 | Durumwheat (<i>Triticumdurum</i>) | Italy |
| Marzak | Durumwheat (<i>Triticumdurum</i>) | Morocco |

300

301 Table 2. Analysis of variance (ANOVA) for the effects of Variety and NaCl concentration on
302 germination and growth parameters (mean squares).

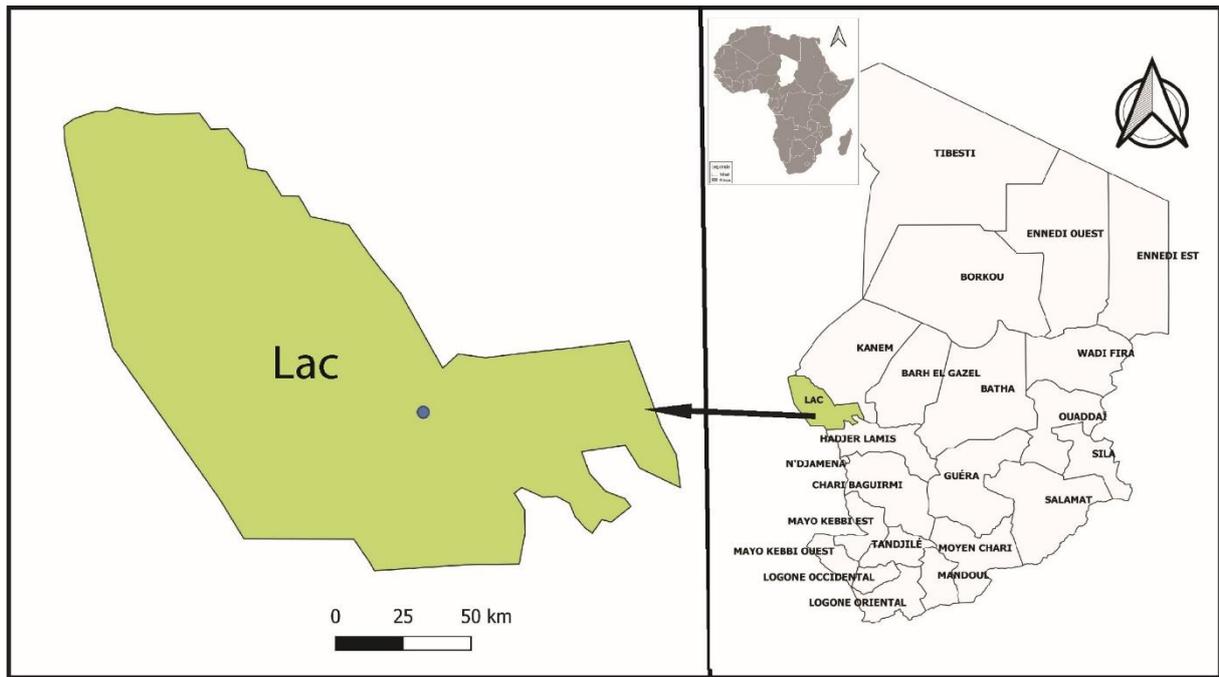
| Source of variation | DF | SG | RG | STI | GSI | GP |
|---------------------|----|----------|-----------|-------------|------------|-------------|
| Varieties | 4 | 2.33 | 3.43 | 773.61 ** | 245.80 *** | 1326.00 *** |
| NaCl concentration | 4 | 19.75*** | 41.86 *** | 2062.81 *** | 128.19 *** | 1298.50 *** |
| Residuals | 16 | 1.17 | 3.75 | 97.73 | 4.44 | 23.50 |

303 ***p<0,001 ; **p< 0,01 ; *p< 0,05

304

305

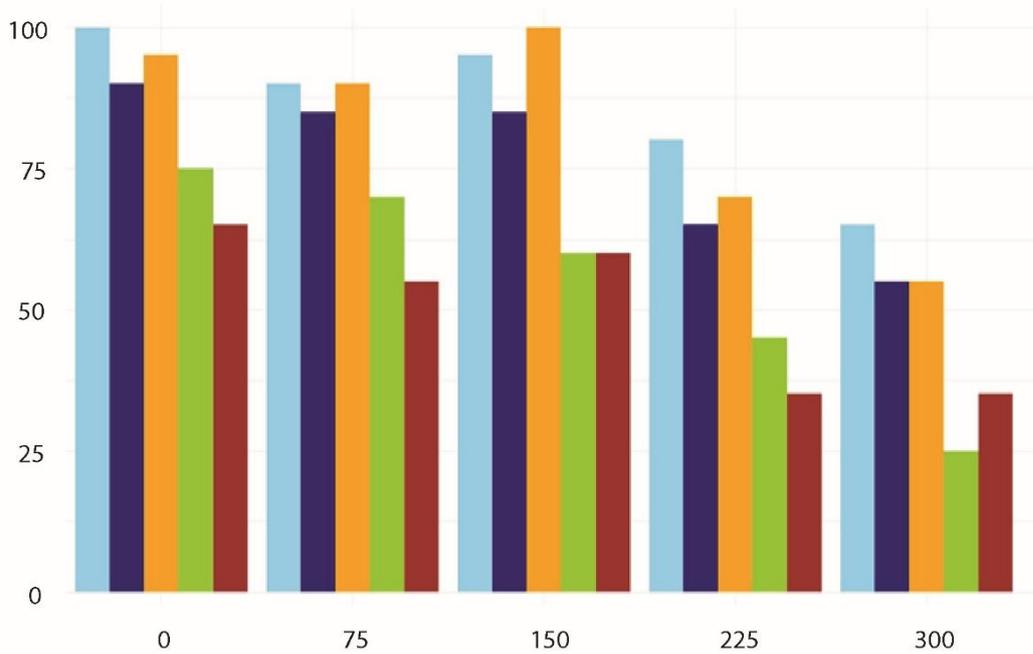
306



307

308

Figure 1.



309

310

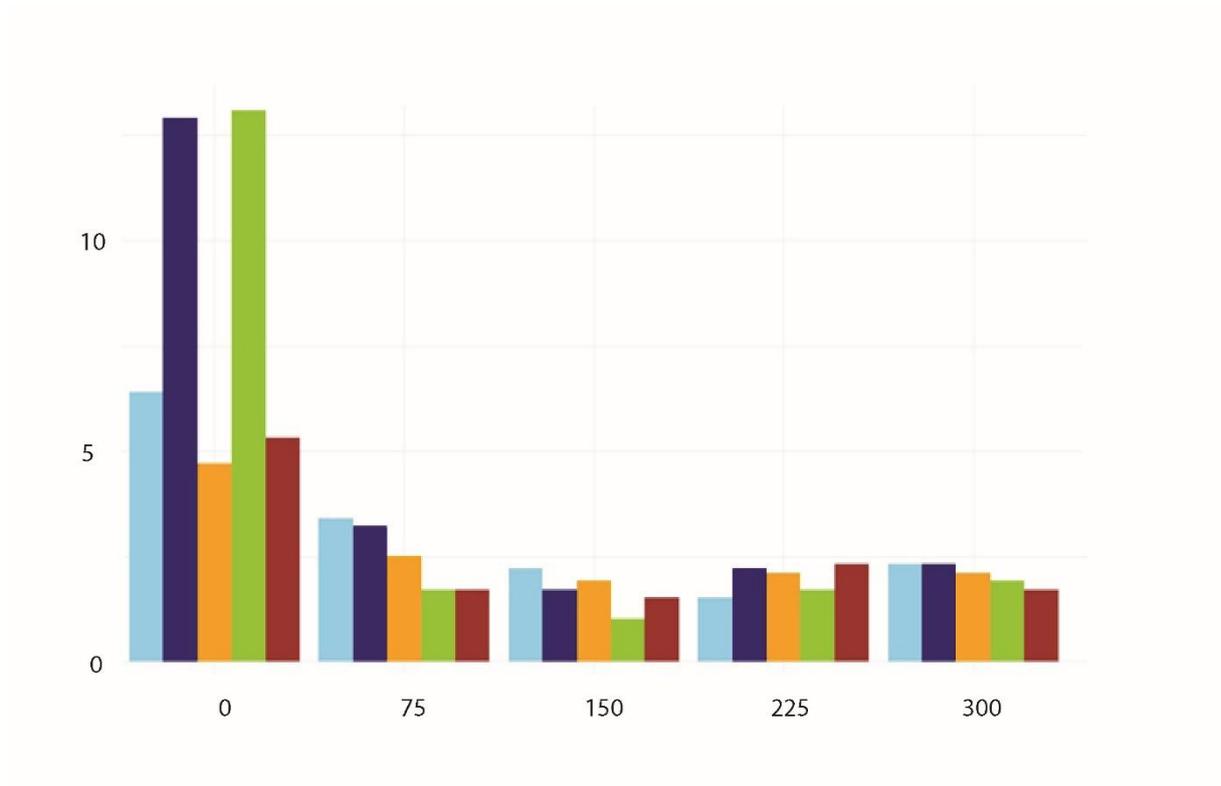
Figure 2.

311

312

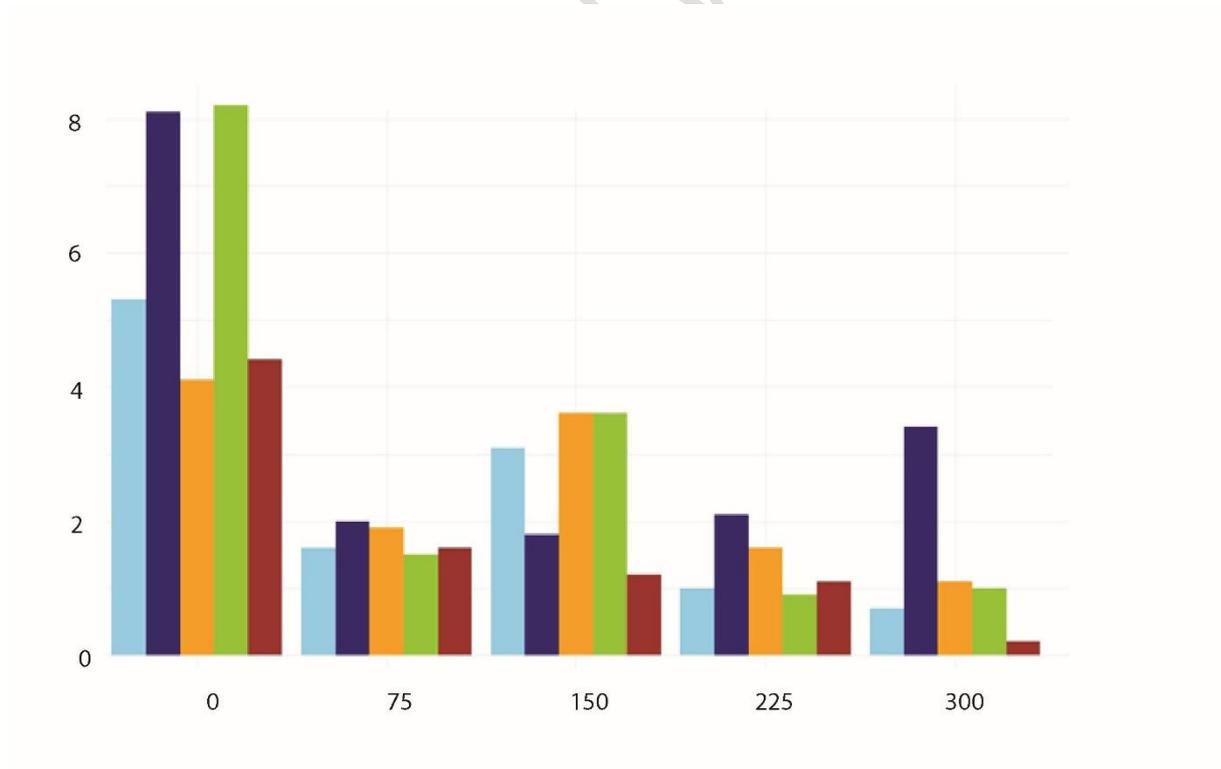
313

314



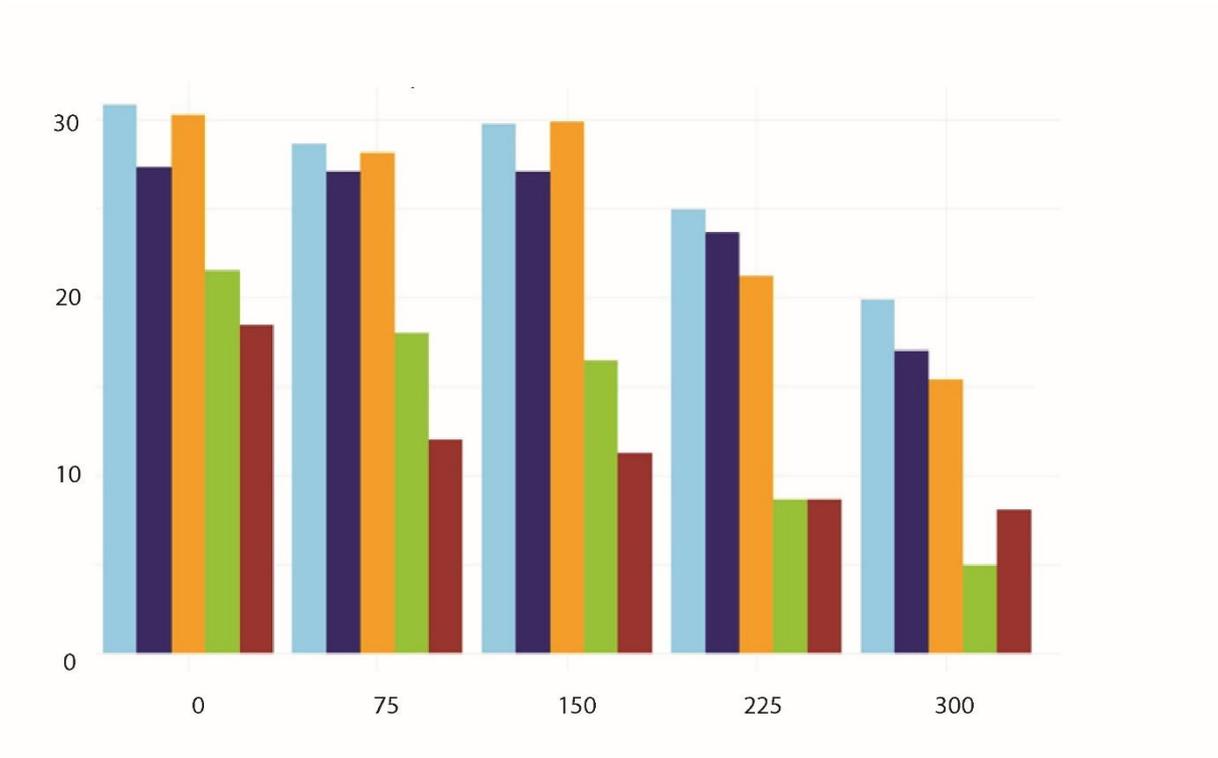
315

316 **Figure 3.**



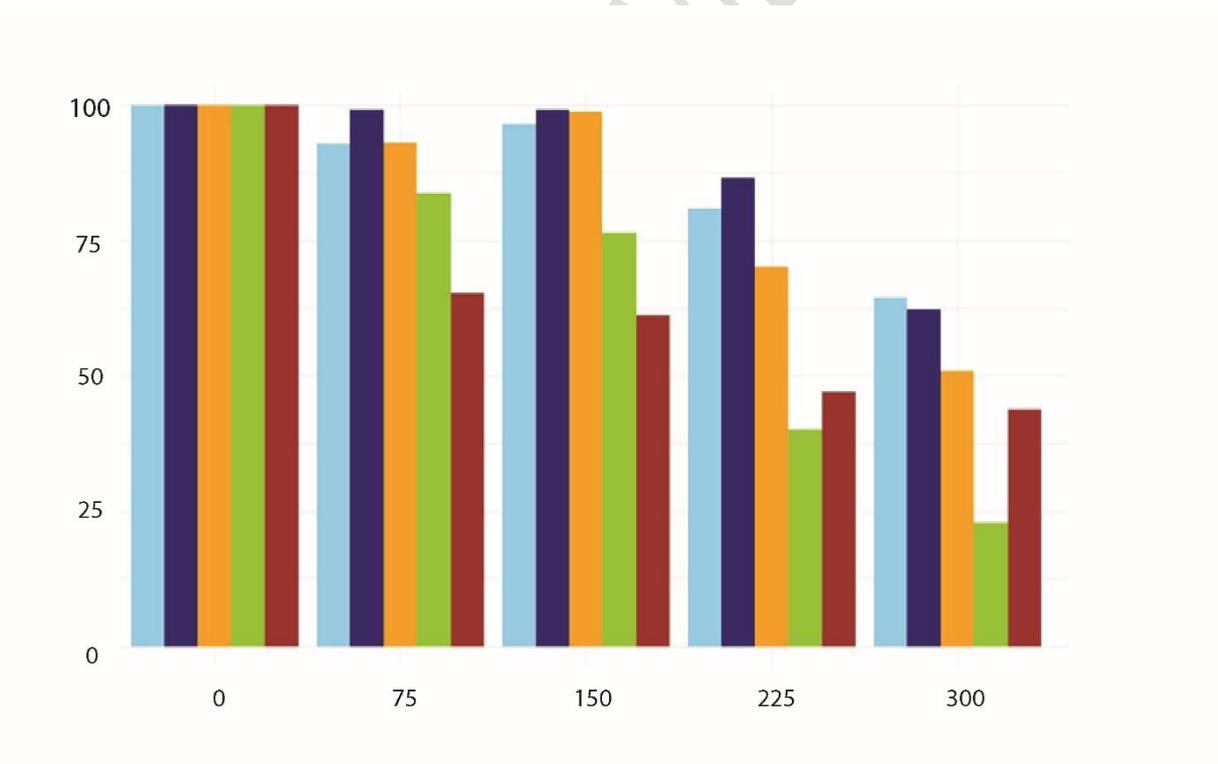
317

318 **Figure 4.**



319

320 **Figure 5.**



321

322 **Figure 6.**

323

324

325

326 **Legend figure:**

327 Figure 1. Location of the experimental site in the Lac Province, Chad. The left panel shows the Lac
328 Province with the experimental site indicated by a blue dot, while the right panel presents the
329 administrative map of Chad highlighting the Lac Province.

330 Figure 2. Germination percentage (GP) of five wheat varieties under different NaCl concentrations,
331 measured on day 7 after sowing. Bars represent varieties Penjamo (light blue), Soms 90 (dark blue),
332 Mexipack (orange), Duilio (green) and Marzak (brown).

333 X: NaCl concentrations (mM)

334 Y: germination percentage (%)

335 Figure 3. Effect of different NaCl concentrations on root growth of seedlings from five wheat varieties,
336 expressed as mean root length (cm) after seven days of experimentation. Bars represent varieties
337 Penjamo (light blue), Soms 90 (dark blue), Mexipack (orange), Duilio (green) and Marzak (brown).

338 X: NaCl concentrations (mM)

339 Y: Root growth (cm)

340 Figure 4. Effect of different NaCl concentrations on shoot growth of seedlings from five wheat
341 varieties after seven days of exposure. Bars represent varieties Penjamo (light blue), Soms 90 (dark
342 blue), Mexipack (orange), Duilio (green) and Marzak (brown).

343 X: NaCl concentrations (mM)

344 Y: Shoot growth (cm)

345 Figure 5. Variation in the Germination Speed Index (GSI) of five wheat varieties under different NaCl
346 concentrations. Bars represent varieties Penjamo (light blue), Soms 90 (dark blue), Mexipack
347 (orange), Duilio (green) and Marzak (brown).

348 X: NaCl concentrations (mM)

349 Y: Germination Speed Index (GSI)

350 Figure 6. Variation in the Salt Tolerance Index (STI) of five wheat varieties under different NaCl
351 concentrations. Bars represent varieties Penjamo (light blue), Soms 90 (dark blue), Mexipack
352 (orange), Duilio (green) and Marzak (brown).

353 X: NaCl concentrations (mM)

354 Y: Salt Tolerance Index STI (%)