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Response of Numbu Sorghum (*Sorghum bicolor* L. cv Numbu) Seedling Growth to Different NaCl Doses

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Abstract

Background: *Seed germination is the initial stage of plant development, involving the activation of complex metabolic processes that support embryonic growth and the establishment of normal seedlings. This study aimed to determine the effects of salinity on the germination rate and uniformity of sorghum seeds.* **Methodology:** *The experiment was conducted using a Completely Randomized Design (CRD) with a single factor, namely NaCl concentration. Five NaCl concentrations were applied: 0, 5, 10, 15, and 20 g/500 mL of water. Seeds of Sorghum bicolor L. cv. Numbu were exposed to each treatment for 60 minutes. Each treatment was replicated three times and randomly assigned to minimize the influence of environmental variation. The observed parameters were seedling fresh weight, seedling height, root length, and germination percentage.* **Findings:** *The results indicated that NaCl dose significantly affected germination percentage, seedling height, and seedling fresh weight, but had no significant effect on root length in the Numbu cultivar.* **Contribution:** *These findings indicate that increasing salinity (NaCl concentrations) can impair seed germination and early seedling growth in the Numbu cultivar of sorghum, particularly in terms of seedling biomass, height, and germination percentage. This study provides preliminary information on the salinity responses of the Numbu sorghum cultivar, which may serve as a reference for assessing its potential cultivation under saline conditions.*

Keywords: *Germination; Numbu; Salinity; Seedling growth; Sorghum*

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INTRODUCTION

Seed germination is the initial phase that determines the success of plant growth, as it involves the activation of complex metabolic processes that support embryo development into normal seedlings (Riansyah et al., 2026; Sudewi et al., 2026; Maksum et al., 2020). In cereal crops such as sorghum (*Sorghum bicolor* (L.) Moench), successful germination is determined not only by seed viability but also by the ability of seeds to respond to unfavorable environmental conditions (Anggraini et al., 2020). One environmental factor receiving increasing attention is salinity, which is a major constraint on agricultural land in many parts of the world, particularly in arid and semi-arid regions (Wahyuni et al., 2019).

Soil salinity, which is generally caused by the accumulation of salts such as sodium chloride (NaCl), can affect germination through two main mechanisms: osmotic stress and ion toxicity. Osmotic stress inhibits water uptake by seeds, thereby slowing imbibition, the initial stage of germination (Prabhandaru & Saputro, 2017). Meanwhile, ion toxicity resulting from the accumulation of Na^+ and Cl^- ions can damage cell structures and disrupt the activity of enzymes involved in germination metabolism. The combined effects of these mechanisms often reduce germination percentage, delay radicle emergence, and impair early seedling growth (Sari et al., 2023).

Sorghum is recognized as a relatively salt-tolerant crop, and Numbu is one of its varieties. This variety is widely cultivated because of its palatability and suitability for dryland conditions. It can adapt to drought and marginal environments (Nasution et al., 2023; Ezward et al., 2019) compared with other cereals; however, its response to salinity during germination still varies considerably among varieties (Sihono et al., 2022). Previous research has reported that an NaCl concentration of 16 g/L resulted in only 27% survival of Numbu sorghum seedlings. Salinity can also reduce the germination rate and uniformity of sorghum and inhibit root and plumule growth. This indicates that, although sorghum is adapted to environmental stress, the germination stage remains sensitive to salinity stress (Samanhudi et al., 2021).

In addition to genetic factors, salinity tolerance during germination is influenced by seed physiological condition and pre-treatment techniques (seed priming) (Asmono et al., 2026), which may improve stress tolerance (Wirnas et al., 2022). Therefore, investigating the effects of higher salinity doses on sorghum germination is important for identifying tolerant varieties and developing effective seed-management strategies (Prabhandaru & Saputro, 2017) to improve crop establishment on saline land. Based on this background, the research question was: how does salinity affect the rate and uniformity of sorghum seed germination? This study aimed to determine the response of Numbu sorghum seedlings to high NaCl doses.

MATERIALS AND METHODS

Research site and period

The research was conducted at the Agronomy Laboratory, Faculty of Agriculture, Graha Nusantara University, Padangsidimpuan, from May 2026.

Materials and equipment

The materials consisted of Numbu sorghum seeds obtained from the Indonesian Cereals Research Institute (Balitsereal), Maros, South Sulawesi; NaCl salt at the specified doses; seed trays; and water. The equipment included an analytical balance, Petri dishes, a ruler, writing materials, paper, and a camera for documentation.

Experimental design

This study used an experimental method with a Completely Randomized Design (CRD) consisting of one factor, namely NaCl dose. The NaCl treatments were 0, 5, 10, 15, and 20 g per 500 mL of water, applied to the Numbu variety for 60 minutes. Each treatment was replicated three times. Five seeds were used in each experimental unit.

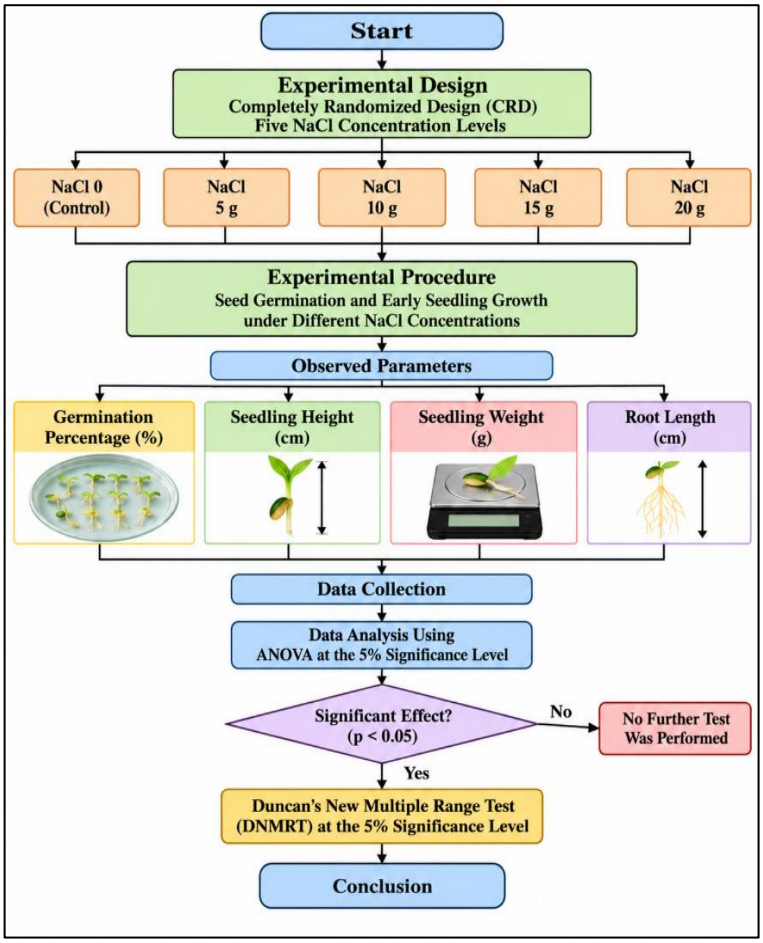


Figure 1. Experimental workflow

The experiment began with the preparation of a Completely Randomized Design (CRD). This design was selected because the treatments were applied under relatively homogeneous experimental conditions, and each experimental unit had an equal chance of receiving any treatment. Sodium chloride (NaCl) was applied at five

dose levels: 0, 5, 10, 15, and 20 g per 500 mL of water. The 0-g NaCl treatment served as the control, while the increasing NaCl doses were used to determine seedling responses to increasing salinity stress. Each treatment was replicated three times.

After the treatments had been established, the seeds were germinated in seed trays treated with the respective NaCl doses. Germination and early seedling growth were carried out under uniform environmental conditions across all treatments. Maintaining uniform environmental conditions was necessary to ensure that the observed differences in responses could primarily be attributed to the different NaCl doses.

Observations were subsequently conducted when the seedlings were 7–30 days after planting (DAP), focusing on several seedling growth parameters. The first parameter was germination percentage, which describes the ability of seeds to produce normal seedlings after NaCl treatment. Germination percentage was expressed as a percentage and used as an initial indicator for evaluating the effect of salinity on germination success. Normal seedlings were defined as those with a healthy, well-developed, non-rotting primary root and secondary roots.

The second parameter was seedling height, which was measured to assess shoot development. Changes in seedling height at different NaCl doses may indicate growth responses to salinity stress. Increasing NaCl concentrations may reduce water availability to seeds and seedlings, thereby inhibiting cell elongation and shoot growth. The criteria for seedling height assessment included well-developed cotyledons and a normally developed, non-rotting plumule.

The third parameter was seedling weight. Fresh weight was used as an indicator of biomass accumulation during early growth. Differences in weight among treatments may reflect changes in the seedling's ability to absorb water, utilize food reserves, and carry out metabolic processes. Increasing salinity stress may inhibit biomass formation when the seedling's ability to maintain water and ion balance is disrupted.

The fourth parameter was root length, measured on normally developed primary roots. Roots are organs that directly interact with the germination medium; therefore, their response to increasing NaCl concentrations is an important indicator for evaluating salinity tolerance. Root growth inhibition may occur because of the low osmotic potential of the medium and disturbances in ionic balance at higher salt concentrations. Data for all parameters—germination percentage, seedling height, seedling weight, and root length—were collected from each experimental unit and replicate. The data were then statistically analyzed to determine whether differences among treatments represented responses to NaCl treatment or experimental variation.

Statistical analysis

The data were analyzed using analysis of variance (ANOVA) at the 5% significance level, in accordance with the experimental design. ANOVA was used to test whether NaCl dose affected each observed parameter. The test criterion was based on the probability value (p-value) at a 5% significance level. If $p < 0.05$, the NaCl treatment was considered to have a significant effect on the parameter analyzed. Conversely, if $p \geq 0.05$, there was insufficient statistical evidence to establish a significant difference among treatments.

When the ANOVA results indicated a significant effect, the analysis was followed by Duncan's New Multiple Range Test (DNMRT) at the 5% level to identify which treatments differed significantly. The results of this post-hoc test are generally presented using letter annotations beside the mean values. Means followed by the same letter are not significantly different, whereas means followed by different letters are significantly different at the 5% level.

The final stage involved interpreting the results. The analysis was used to explain seedling response patterns to increasing NaCl doses based on germination percentage, seedling height, seedling weight, and root length. By comparing responses at 0, 5, 10, 15, and 20 g NaCl per 500 mL of water, trends in seedling growth changes caused by salinity stress could be identified.

Overall, the workflow comprised the establishment of the CRD, application of five NaCl doses, the germination process, measurement of growth parameters, data collection, ANOVA at the 5% level, DNMRT at the 5% level when significant effects were detected, and interpretation and conclusion drawing. This sequence enabled the effects of increasing NaCl doses on germination capacity and early seedling growth to be analyzed systematically and on the basis of statistical evidence.

RESULTS AND DISCUSSION

NaCl application can affect the germination process and seedling growth in sorghum because increasing salt concentrations alter the osmotic potential of the germination medium. This condition can inhibit water uptake by seeds and consequently disrupt the physiological processes required for germination (Al Adawiyah et al., 2023). In addition to osmotic pressure, increasing concentrations of Na^+ and Cl^- may cause ionic imbalance and metabolic disturbances in seedling tissues. A decline in germination percentage as NaCl dose increases indicates that higher salinity can inhibit the early germination process. High salt concentrations lower the water potential of the surrounding environment, requiring seeds to expend more energy and time for imbibition. Water uptake is an essential stage in reactivating seed metabolism, including enzyme activity, respiration, and the mobilization of food reserves (Pamungkas et al., 2021). Therefore, limited water availability due to osmotic pressure may delay radicle emergence and reduce the proportion of seeds that successfully germinate.

The analysis of variance presented in Table 1 showed a significant effect of NaCl on sorghum germination percentage. Sorghum responses differed among the doses, and germination percentage decreased as the dose increased. The 20-g dose produced the poorest germination response, at 1.2%, indicating that the seeds were barely able to withstand NaCl exposure.

The analysis of variance presented in Table 1 showed that NaCl significantly affected sorghum seedling height. Responses differed among doses, and seedling height generally declined as the dose increased. The 20-g dose produced the lowest seedling height, at 1.30 cm, indicating severe growth inhibition under NaCl stress. The analysis of variance presented in Table 1 showed that NaCl did not significantly affect sorghum root length. Responses varied among doses, and root length tended to

decrease as the dose increased. The 10-, 15-, and 20-g doses produced the shortest roots, suggesting that these NaCl levels strongly constrained root growth.

Table 1. Effects of NaCl doses on germination percentage, seedling height, root length, and seedling fresh weight

No.	NaCl dose (g/500 mL water)	Germination (%)	Seedling height (cm)	Root length (cm)	Seedling fresh weight (g)
1	0	95.0 e	13.50c	5.03	1.41 b
2	5	50.0 d	6.86b	5.56	0.57 a
3	10	20.0 c	7.06b	1.80	0.59 a
4	15	10.0 b	6.53b	1.86	0.54 a
5	20	1.2 a	1.30a	1.13	0.13 a

Note: Values followed by the same lowercase letter are not significantly different according to DNMRT at the 5% level; Values followed by different lowercase letters are significantly different according to DNMRT at the 5% level; Values without lowercase letter annotations are not significantly different according to ANOVA.

The analysis of variance presented in Table 1 showed that NaCl significantly affected sorghum seedling fresh weight. Responses differed among doses, and fresh weight decreased as the dose increased. The 20-g dose produced the lowest seedling fresh weight, at 0.13 g, indicating severe inhibition under NaCl stress. Seed germination percentage is one of the main indicators used to determine the physiological quality of seeds. This parameter reflects the ability of seeds to germinate and develop into normal seedlings under optimal environmental conditions. A high germination percentage indicates good seed viability, whereas a low percentage suggests a decline in seed quality due to internal or external factors (Al Adawiyah et al., 2023; Ayu et al., 2021).

Physiologically, germination begins with imbibition, the absorption of water by dry seeds, which activates metabolic enzymes. Enzyme activity then triggers the breakdown of food reserves, such as carbohydrates, proteins, and fats, into simple compounds that serve as energy sources for embryo growth. The subsequent stage includes radicle emergence, which is an early sign of successful germination (Panataria et al., 2025; Jannah et al., 2024). Cell membrane integrity and enzyme activity also play important roles in determining germination success (Sari et al., 2023). Adequate water availability is required for imbibition; however, excess water can create anaerobic conditions that inhibit respiration (Anggraini et al., 2020). Proper storage management is essential for maintaining seed viability (Maksum et al., 2020). In research contexts, germination percentage is often associated with seed vigor, which provides a more comprehensive indication of a seed's ability to grow under suboptimal conditions (Anggraini et al., 2020).

Physiologically, increases in seedling height are influenced by cell division and elongation, particularly in meristematic tissues. Plant hormones such as auxin and gibberellin play important roles in stimulating cell elongation and thus contribute to seedling height growth. Hormonal activity is strongly influenced by the internal condition of the seed and external environmental factors (Sari et al., 2023).

Seedling height is also closely related to seed quality. High-vigor seeds generally produce taller and more uniform seedlings than low-vigor seeds. This is attributable to their ability to mobilize food reserves efficiently to support embryo growth. Food reserves such as starch, proteins, and lipids are broken down to provide energy for the development of new tissues (Rosmala et al., 2025). Under low-light conditions, seedlings tend to undergo etiolation, characterized by elongated but weak growth (Pranata & Afrianti, 2020).

Physiologically, root elongation is influenced by cell division and elongation in the root apical meristem. This process is regulated by the balance of plant hormones, particularly auxin, cytokinin, and gibberellin. Auxin plays a dominant role in stimulating root-cell elongation, while its interaction with other hormones determines the direction and rate of root growth. This hormonal activity is strongly influenced by the internal condition of the seed and external factors during germination (Suherni et al., 2021; Widyastuti et al., 2025).

Root length is also closely related to the seed's ability to mobilize food reserves. High-vigor seeds can provide sufficient energy to support optimal root growth. Conversely, low-quality seeds tend to produce short and weak roots because of limited energy reserves and physiological disturbances during germination (Hazra et al., 2024; Safitri et al., 2021).

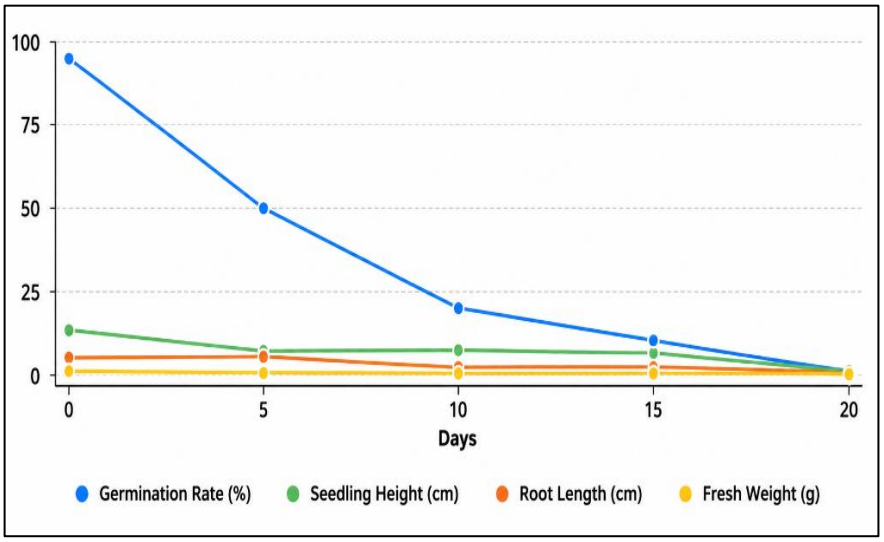


Figure 2. Germination of Numbu sorghum seeds under salinity stress
The values in the graph represent percentages relative to the control (0 NaCl dose = 100%). This approach was used to display germination percentage (%), seedling height (cm), root length (cm), and fresh weight (g) in a single graph.

Temperature also affects enzyme activity and metabolic rate. Optimal temperatures promote root growth, whereas extreme temperatures can reduce physiological activity (Prasetyo & Hermiyanto, 2022). The growth medium and nutrient availability also influence root length. A loose, well-aerated medium facilitates root penetration and supports greater root elongation. Nutrients such as phosphorus play an important role in root-system development because they are involved in the

production of energy (ATP) required for cell growth. Deficiencies in certain nutrients can inhibit root growth (Jannah et al., 2024).

In research, root length is often used as a parameter to evaluate the effects of treatments such as plant growth regulators, seed treatments, and variations in environmental conditions. Root length is usually measured during the early growth stage to obtain an indication of the plant's response to the treatment. The resulting data are then statistically analyzed to determine the significance of differences among treatments (Al Adawiyah et al., 2023).

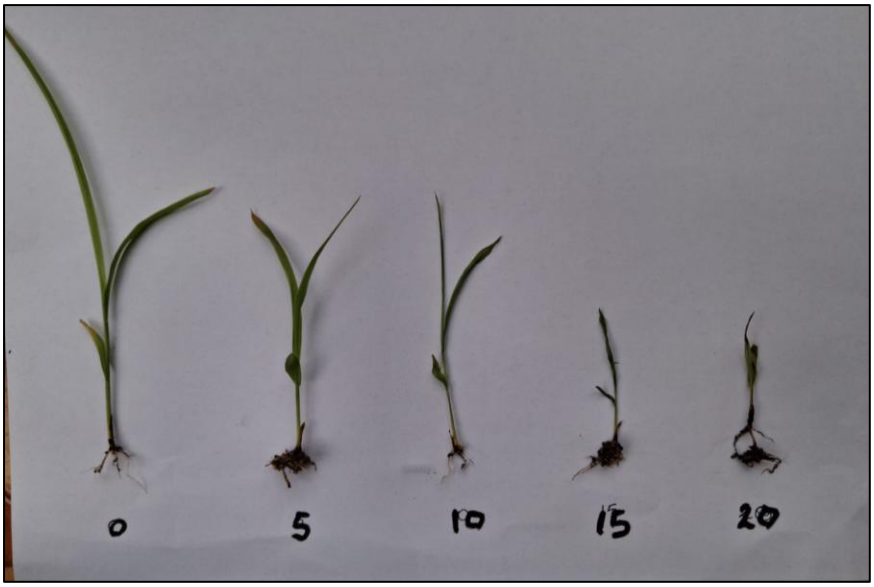


Figure 3. Morphological Characteristics of Numbu Sorghum Seedlings at Different NaCl Doses

Physiologically, seedling fresh weight is strongly influenced by tissue water content, photosynthetic products, and the metabolism of food reserves. During early growth, an increase in fresh weight is primarily attributable to imbibition and cell elongation, which depend on turgor pressure. Water absorbed by seeds activates enzymes involved in hydrolyzing food reserves, such as starch, proteins, and lipids, into simpler compounds. These compounds are subsequently used as energy sources and as building materials for new tissues (Zhao et al., 2018).

Internal factors such as seed quality and vigor have a major influence on seedling fresh weight (Anggraini et al., 2020). High-vigor seeds have more efficient metabolic capacity, enabling them to mobilize food reserves optimally to support growth. This results in seedlings with more developed tissues and greater fresh weight than seedlings produced by low-vigor seeds (Koyoto et al., 2017; Tarigan et al., 2018). In research, seedling fresh weight is often used to evaluate the effects of treatments such as plant growth regulators, seed priming, and variations in growing media. Fresh weight is measured by weighing seedlings immediately after harvest to avoid water loss that could affect the measurement (Munarti et al., 2022). The resulting data are then analyzed to determine differences among treatments and their relationships with other growth parameters. The description above is supported by Figure 3, which shows that

salt stress can affect the quality of sorghum seedlings. Increasing salt doses affect seedling morphology, particularly the plumule and radicle (Susilo et al., 2021). At higher salt doses, sorghum seedlings have increasing difficulty surviving and may eventually die.

CONCLUSION

The study showed that different NaCl doses affected germination percentage, seedling height, and seedling fresh weight, but did not significantly affect root length. The best response was observed at an NaCl dose of 5 g, whereas the poorest response occurred at 20 g NaCl.

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