JSIANE : Vol. 3, Issue 4, 2023, Page 31-33 ISSN (Online) 2583-2093

Journal of Science Innovations and Nature of Earth

Journal homepage : www.jsiane.com

Effect of Salt Treatments on *Amaranthus viridis* Plant Germination and Growth

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www.doi.org/10.59436/jsiane.com/archives3/4/111

Abstract

During the germination and early seedling phases, the effects of three salinity levels—0, 100, 150, and 300 mM NaCl on *Amaranthus viridis* were studied. The effects of salt stress on different germination and physiological features were revealed by this laboratory pot experiment, which was planned as a fully randomised study with three replications for each salinity level. Interestingly, the greatest detrimental impacts were noticeable when seeds were exposed to 300 mM NaCl, highlighting the significant effects of excessive salinity on *Amaranthus viridis* germination and early growth. These results advance our knowledge of the ways salinity affects the critical early stages of *Amaranthus viridis* development.

Keywords : Salinity, Germination, NaCl

Received 08.09.2023 **Revised 14.10.2023** **Accepted 23.12.2023**

Introduction

Amaranthus, a diverse genus encompassing around 70 species, thrives in tropical and subtropical regions like Southeast Asia. Among its various types, widely consumed in Southeast Asia, this species is esteemed as the most economically vital crop within the genus. Nevertheless, its demand fluctuates in tandem with endeavours to enhance nutritional value and productivity. Amaranthus tricolor, a widely cultivated variety, stands out for its utilization as a vegetable due to its notable protein content. The agricultural landscape, particularly in Southeast Asia, is shaped by the dynamic interplay of cultivation practices and the evolving demand for this valuable Amaranthus species (Siswanthi & Khairunnisa, 2021; Andini *et al*., 2013).

Some varieties of Amaranthus are used as decorative plants or have medicinal qualities (Das, 2016). This genus is globally acclaimed for its tolerance to heat, drought, and salinity stress (Riggins *et al*., 2021), making it a potential alternative crop in temperate regions (Mlakar *et al*., 2010). However, many Amaranthus species exhibit noxious weed characteristics, marked by high invasiveness and some being classified among the world's most troublesome weeds. With a C4 metabolic pathway, prolific seed production, and rapid growth, they efficiently compete for water, nutrients, and light, establishing themselves as formidable adversaries to cultivated crops (Assad *et al*., 2017).

Soil salinity, arising from accumulated salt concentrations, adversely impacts plant growth as a form of abiotic stress. Na+ and Cl- ions, the culprits in this salt content, disrupt plant cells, causing ion imbalance and physiological changes. Excessive Na+ inhibits K+ absorption, crucial for plant growth, development, and productivity. Elevated root salt concentration stems from agricultural practices like irrigation or natural processes. Soil salt inhibits plant growth and productivity, disrupting metabolic processes critical for germination, seed growth, vegetative phases, flowering, and fruit formation. Salinity induces osmotic stress, interrupts ion transport, and creates a toxic environment, negatively impacting cell activity due to sodium and chloride accumulation (Volkov & Beilby, 2017).

This study aimed to assess the salinity tolerance of Amaranthus viridis, sourced from the local area of Shikohabad. The investigation involved determining how salt (0 to 300 mM NaCl) affected the growth characteristics and rate and germination of seeds.

Material and Methods

The experiment conducted at the Department of Botany, Narain College Shikohabad, this study focused on *Amaranthus viridis* seeds. It comprised a control (seeds in distilled water) and three treatments (seeds in 100 mM, 150 mM, and 300 mM NaCl concentrations), each with three replicates, offering a thorough examination of germination under diverse sodium chloride levels.

1. **1. Experimental Design-** A pot experiment assessed the physiological impact of NaCl on Amaranthus viridis. Ten surface-sterilized seeds of uniform size were planted in pots (30 cm long, 25 cm diameter) filled with nutrient-rich soil. Different concentrations of NaCl (Control, 100, 150, 300 mM) were applied, with three replicates for each concentration. Sodium chloride solutions were administered bi-weekly. After the treatments, samples were collected from each group for analysis of various physiological parameters. This controlled experiment aimed to elucidate the specific effects of NaCl on the physiological aspects of Amaranthus viridis, providing valuable insights into its response to salt stress.

2. Germination percentage- Seed germination in each treatment was monitored daily for 12 days post the experiment's initiation. At one millimetre in length, the radical was said to have germinated.

The formula (Imtiyaz *et al*., 2014) was used to determine the germination percentage.

$$\text{Germination percentage)} = \frac{\text{Total number of germinated seeds}}{\text{Total number of seeds}} \times 100$$

3. Root and shoot length (early seedlings growth) - Root and shoot lengths were measured using a scale, and readings were recorded for both treated and control plants, following the methodology (Heenan *et al*.,1988).

4. Leaf area- The conventional graph paper method was used to compute the leaf area. The length and width of the squares enclosed by the contour of a leaf were measured. After the operation, three leaves on average from each treatment, each in triplicate, were taken for observation (Taghipour & Saheli, 2008).

5. Number of leaves per shoot- Leaf count per shoot was recorded on the first day of germination for each treatment.

Results and Discussion

Salinity stress, induced by varying NaCl concentrations, was examined for its impact on germination percentage, root and shoot length, leaf area, and number of leaves per shoot. The results from these parameters are detailed under the respective headings, providing insights into the effects of salinity on plant growth.

1. Effect of salt concentration on germination- Table No. 1 highlights the adverse impact of NaCl on *Amaranthus viridis* L. seed germination. Compared to the control, higher NaCl concentrations resulted in reduced germination percentages of 80%, 75%, and 70% in 100 mM, 150 mM, and 300 mM, respectively. Control plants exhibited a maximum germination rate of 90%. The diminished germination is attributed to the inhibition of plant growth induced by salinity stress, underscoring the sensitivity of *Amaranthus viridis* L. to elevated NaCl levels during the germination phase.

Table No.1 Effect of sodium chloride (NaCl) on *Amaranthus viridis* of germination percentage.

Experiment	Concentration	Germination percentage
Control	0	90 %
NaCl	100 mM	80 %
	150 mM	75 %
	300 Mm	70 %

2. Root and shoot length- Salinity, specifically NaCl, demonstrated a detrimental impact on both root and shoot lengths of *Amaranthus viridis* L. The notable reduction in these lengths due to salinity stress is evident in Tables 2 and 3.

Table No. 2 Effect of sodium chloride on *Amaranthus viridis* of root length

Experiment	Concentration	Root length
Control	0	4.9 cm
NaCl	100 mM	4.4 cm
	150 mM	3.7 cm
	300 mM	3.4 cm

Table No. 3 Effect of sodium chloride on *Amaranthus viridis* of shoot length

Experiment	Concentration	Shoot length
Control	0	13.2 cm
NaCl	100 mM	12.2 cm
	150 mM	12.4 cm
	300 mM	10.3 cm

4. Leaf Area- Leaf area substantially decreased with increasing NaCl concentrations (100 mM, 150 mM, 300 mM). Compared to the control (37.5 cm2), the leaf area diminished to 17.74 cm2 at the 300 mM concentration (Table 4).

Table No. 4 Effect of sodium chloride on *Amaranthus viridis* of leaf area.

Experiment	Concentration	Leaf area
Control	0	37.5 cm^2
NaCl	100 mM	29.6 cm^2
	150 mM	28.5 cm^2
	300 mM	17.74 cm^2

5. Number of leaves per shoot- The study revealed that salinity impacts the number of leaves per shoot in Amaranthus viridis. At high concentrations (100 mM, 150 mM), NaCl showed inhibition, with 12.33 and 11.20 leaves per shoot, respectively. The control exhibited the maximum number of leaves per shoot at 15.00 in *Amaranthus viridis* (Table 5).

Table No. 5 Effect of sodium chloride on *Amaranthus viridis* of number of leaves per shoot.

Experiment	Concentration	Number of leaves per Shoot
Control	0	15.00
NaCl	100 mM	12.33
	150 mM	11.20
	300 mM	09.60

Seed germination, a pivotal stage in plant biology, is highly vulnerable to adverse environmental conditions. Salinity, a significant stressor, can severely impede or entirely halt germination in crops. Salt stress's osmotic effect decreases dry seeds' absorption of water, impeding the crucial imbibition step that leads to germination. The relationship between salinity and Na+ and Cl- toxicity impairs energy generation, respiration, and the metabolism of nucleic acids and proteins. This results in an excess of reactive oxygen species (ROS) building up and damages cellular structures (Mwando *et al*., 2020). Plant hormones such as gibberellin (GA) and abscisic acid (ABA) control germination (Han & Yang, 2015). GA enhances germination by upsetting dormancy, whereas ABA encourages hibernation and hinders germination (Shanker & Venkateswarlu, 2021). The hormones become unbalanced in saline environments, which further inhibits seed germination.

Amaranthaceae encompasses taxa recognized for their high salt tolerance during the germination stage. Various genera, including Salicornia, Suaeda, and Sarcocornia, have demonstrated germination resilience under NaCl concentrations surpassing 1 M (Chapman,1960; Wang *et al*., 2008; Redondo *et al*., 2004). In quinoa, significant germination inhibition was noted at 300–500 mM NaCl, although some cultivars exhibited no impact at 300 mM NaCl compared to control conditions (Adolf *et al*., 2013). Even among genotypes within the same species, amaranths, which are renowned for their capacity to withstand low to moderate salt during germination, show significant heterogeneity. Notably, at 150 mM NaCl, the toxic plant A. retroflexus from China showed more germination than in control circumstances (Hao *et al*., 2017), while seeds from Queensland (Australia) experienced a 50% drop in germination at just 100 mM NaCl (Khan *et al*., 2022).

Amaranthus species exhibit remarkable salt tolerance across their entire life cycles (Estrada *et al*., 2021). Their low basal stomatal conductance, which is the consequence of low stomatal density and aperture and helps prevent leaf water loss in salt stress, is credited with their robustness. Their morphological adaptations, such as a well-developed root system and C4 metabolism, further enhance their resistance to a variety of environmental challenges, such as salinity and drought (Assad *et al*., 2017). Recognized as pseudocereals of the future alongside quinoa, grain amaranth species, investigated here in concentrations up to 600 mM NaCl, demonstrated survival for one month. A. albus displayed higher salt tolerance during germination, while A. hybridus proved more resilient during vegetative growth, emphasizing species-specific responses to salinity.

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Cite this article:
Mridula Yadav, 2023, "Effect of Salt Treatments on *Amaranthus viridis* Plant Germination and Growth" *Journal of Science Innovations and Nature of Earth*, Vol. 3(4), page-31-33
www.doi.org/10.59436/jsiane.com/archives3/4/111