Impact of salinity stress on the response of aloe vera from different breeders on coastal sand land

Rennanti Lunnadiyah Aprilia[1*], *Edi* Purwanto[2], *Venty* Suryanti[3], *Muji* Rahayu[2]

[1]Doctoral Program of Agriculture Sciences Departement, Faculty of Agriculture, Universitas Sebelas Maret, Indonesia
[2]Faculty of Agriculture, Universitas Sebelas Maret, Indonesia
[3]Faculty of Mathematic and natural Sciences, Universitas Sebelas Maret, Indonesia

Abstract. Climate change has led to increased salinity in coastal areas, which can inhibit plant growth. Aloe vera (Aloe vera L.), a drought-resistant CAM (Crassulacean Acid Metabolism) plant with high economic potential, has the ability to tolerate dry environments but requires further study regarding its ability to withstand salinity stress, especially in coastal sandy soils impacted by climate change. This study aims to analyze the effect of salinity stress on the growth and yield of aloe vera from different nurseries in coastal areas. The experiment was conducted in a greenhouse using a completely randomized design with two factors: nursery origin (Gunung Kidul, Bantul, Cilacap) and salinity levels (0, 5, 10, and 20 g NaCl/L). Results showed that salinity stress significantly affected plant growth and yield. Each increase in NaCl concentration reduced growth and yield. Seeds from the Gunung Kidul nursery produced the best results in terms of plant height, number of leaves, leaf area, and fresh leaf weight. The best treatment interaction was found in the Gunung Kidul nursery without NaCl addition, with a leaf area reaching 18,006 cm^2.

1 Introduction

Indonesia is an archipelagic country with over 17,508 islands and a coastline extending 81,000 km. In terms of natural resources, Indonesia has significant coastal resource potential [1]. The vast coastal areas hold great potential for agricultural development. However, developing coastal areas for agriculture faces several challenges. These challenges arise from the nature of sandy soil, which has poor structure, consists of single particles that do not bind together, has a high bulk density, low water retention, and minimal nutrients [2]. Moreover, coastal sandy soil is influenced by tidal properties, sea winds, and salinity [3]. This issue can be addressed by cultivating plants that are capable of adapting to coastal environments. One such plant that can adapt is Aloe vera [4].

These problems can be addressed by cultivating plants that can adapt to the coastal environment. Aloe vera is one such plant that can adapt to these conditions. Aloe vera, a

* Corresponding author: renantihadeejah@gmail.com

succulent CAM plant (Crassulacean Acid Metabolism), has the ability to reduce transpiration by closing its stomata during the day. Aloe vera stores water in its leaves, making it suitable for cultivation in dry areas with high temperatures, such as coastal sandy soil [4, 5]. However, climate change causes unpredictable agro-climatic conditions, affecting salinity and environmental conditions [6]. Which can influence the growth and yield of Aloe vera, especially under salinity stress in coastal sandy areas.

Another factor affecting the growth and yield of Aloe vera is the quality of the seeds used. Good growth and yield of Aloe vera depend on the quality of the seeds. Previous studies have shown that the origin of the soil where Aloe vera is cultivated affects plant growth [7]. The origin of the nursery influences the growth and yield of Aloe vera seedlings. It is essential to determine which nursery origin produces seeds that can adapt to coastal sandy areas. Previous research on the cultivation of Aloe vera in coastal sandy soil focused on the use of integrated fertilizers [8]. However, that study did not consider the factors of salinity or the origin of the nursery. Another study examined the effect of salinity stress on Aloe vera's mineral and biochemical content but did not investigate growth responses, nor did it utilize coastal sandy soil or nurseries from Indonesia [9]. The novelty of this research lies in its focus on the specific origin of nurseries, the specific location of coastal sandy soil, and varying levels of salinity. The aim of this study is to determine the impact of salinity stress on the growth response and yield of Aloe vera plants from various nurseries in coastal sandy soil.

2 Methodology

This research was conducted in a greenhouse located in Tegalretno Village, Petanahan District, Kebumen Regency. Geographically, it is located at 7° 46' 16.36" South Latitude and 109° 36' 9.34" East Longitude with an elevation of 10 meters above sea level. The study was conducted from December 2023 to August 2024. The experiment used a completely randomized design (CRD) with two factors. The first factor was the origin of the Aloe vera nurseries (Gunung Kidul (P1), Bantul (P2), and Cilacap (P3)) These three places were chosen based on different altitudes, namely highlands (Gunung kidul), lowlands (Cilacap) and midlands (Bantul), and the second factor was different salinity levels (0 (S0), 5 (S1), 10 (S2), and 20 (S3) g NaCl/L) This level is based on previous research.

This produced 12 treatment combination are P1S0: Seedlings sourced from the Gunung Kidul nursery without the addition of NaCl, P1S1: Seedlings sourced from the Gunung Kidul nursery with the addition of 10 g/L NaCl, P1S2: Seedlings sourced from the Gunung Kidul nursery with the addition of 15 g/L NaCl, P1S3: Seedlings sourced from the Gunung Kidul nursery with the addition of 20 g/L NaCl, P2S0: Seedlings sourced from the Bantul nursery without the addition of NaCl, P2S1: Seedlings sourced from the Bantul nursery with the addition of 10 g/L NaCl, P2S2: Seedlings sourced from the Bantul nursery with the addition of 15 g/L NaCl, P2S3: Seedlings sourced from the Bantul nursery with the addition of 20 g/L NaCl, P3S0: Seedlings sourced from the Cilacap nursery without the addition of NaCl, P3S1: Seedlings sourced from the Cilacap nursery with the addition of 10 g/L NaCl, P3S2: Seedlings sourced from the Cilacap nursery with the addition of 15 g/L NaCl, P3S3: Seedlings sourced from the Cilacap nursery with the addition of 20 g/L NaCl., with each combination replicated three times, resulting in a total of 36 experimental plots. Each plot consisted of 8 plants, including 3 sample plants, 3 destructive plants, and 2 reserve plants, making a total of 288 plants. The planting distance was 60 cm x 60 cm, with the same distance between plots and replicates. The planting hole depth was 15 cm (10). The seedlings used were from the Chinensis miller variety, with an average seedling age of 6 months, consisting of 5 leaves and an average seedling height of 25 cm.

The growing media used consisted of a mixture of coastal sand, goat compost, and rice husk charcoal in a 2:2:1 ratio, with 10 kg of planting media in each polybag [4, 10, 11]. After preparing the media, NaCl was applied according to the treatment levels. Repeated NaCl application mimicked the fluctuating salinity conditions found in nature and allowed for long-term plant adaptation. Salinity application was repeated every two months, based on environmental factors and the growth condition of Aloe vera [12]. Plant maintenance included pest and disease control, watering, weeding, and hilling, as well as the addition of supplementary fertilizer every four weeks using goat compost at a rate of 250 grams per plant.

Parameters observed included initial environmental and daily environmental conditions, growth observations, and yield observations. Initial environmental conditions were measured in terms of soil physical and chemical properties, including pH, available nitrogen (N), phosphorus (P), potassium (K), porosity, permeability, cation exchange capacity (CEC), and initial salinity levels. Daily environmental observations measured light intensity, temperature, and humidity. Growth observations included plant height, number of leaves, leaf length, leaf circumference, and leaf area. Yield observations included fresh weight of leaves, fresh weight of roots, fresh weight of the whole plant, and dry weight of leaves. Growth parameters were observed every two weeks. Data were statistically analyzed using Analysis of Variance (ANOVA) at a 95% confidence level, followed by Duncan's Multiple Range Test (DMRT) at a significance level of 5%.

3 Results and Discussion

3.1 Initial and Daily Observations

Initial environmental observations were conducted to assess the physical and chemical characteristics of the soil at the research site. The parameters analyzed included soil pH, nitrogen (N), phosphorus (P), and potassium (K) content, porosity, permeability, cation exchange capacity (CEC), and initial salinity levels. These data are essential for understanding the soil conditions as a baseline for evaluating plant responses to salinity stress. The data are presented in Table 1. Based on the data, it is possible to carry out research because it suits the needs of the aloe vera plant [13, 14].

Tabel 1. Initial Soil Test Results

Parameter	Test Results	Unit
Soil pH	6,5	-
Nutrient Content Available		
- Nitrogen (N)	10	Ppm
- Fosfor (P)	8	Ppm
- Kalium (K)	120	Ppm
Porosity	42	%
Permeability	15	Cm/jam
Cation Exchange Capacity (CEC)	12	Meq/100 g tanah
Initial Salinity	2	Ppt

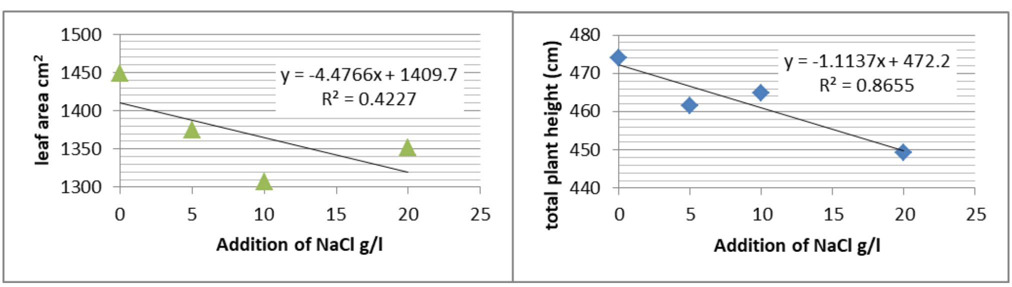
Aloe vera grows optimally at temperatures between 20°C and 30°C. It requires well-drained soil, and the ideal planting medium is a mixture of soil with sand or loose organic matter to allow easy water flow, preventing root rot caused by waterlogging. The ideal soil for Aloe vera has a pH between 6.0 and 7.0 (slightly acidic to neutral) [15]. To monitor daily agroclimatic conditions, daily observations were conducted to record the microclimatic conditions at the research site, including average temperature, humidity, and sunlight intensity. This data is crucial for understanding the daily environmental dynamics that can influence the growth and development of the plants throughout the study. The average daily data is presented in Table 2, and the results indicate that the conditions meet the growth requirements for cultivating Aloe vera.

Table 2. Daily Observation Results

No	Environmental Observation Indicators	Average			Average
		Morning	Afternoon	Evening	
1.	Temperature (°C)	26	44,05	30,77	33,61
2.	Humidity (%RH)	89,55	45,75	69,3	68,20
3.	Light Intensity (Lux)	21935.5	51512.7	1710.1	25052.77

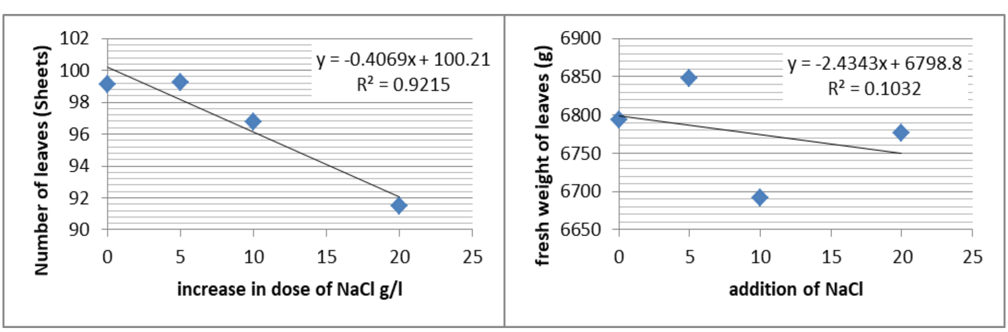
3.2 Effects of Salinity Stress on Growth and Yield

The research results indicated that salinity stress significantly affected the growth and yield of Aloe vera. The relationship between salinity stress and plant performance was reflected in significant changes in various growth parameters, including plant height, number of leaves, leaf area, and final yield. The data confirmed that increasing salinity levels had a negative impact on plant performance. This can be seen in Figures 1 and 2, where correlation and regression analyses show that the addition of NaCl reduced yield. This is consistent with previous research, which states that salinity stress negatively affects plant yield [12 16].



Impact of salinity stress on leaf area Impact of salinity stress on plant height

Figure 1. Relationship between adding NaCl to the growth of aloe vera plants



Impact of salinity stress on leaf number Impact of salinity stress on plant fresh weight

Figure 2. The relationship between the addition of NaCl and the growth of aloe vera plants

The regression equations in Figures 1 and 2 indicate that increasing NaCl concentration has a negative impact on leaf area, plant height, leaf count, and fresh weight of the plant, showing a consistent decline as NaCl concentration increases. The relationship is particularly strong for the leaf count, as the most significant decrease occurs in this parameter, with a reduction of 92.15% [15]. High salinity reduces the osmotic potential around the roots, making it difficult for plants to absorb water. This condition creates water stress, even when water is available in the environment. Consequently, physiological processes such as cell division and elongation are inhibited, leading to reduced plant height, leaf number, and leaf area. The decrease in plant height, leaf number, leaf area, and fresh leaf weight supports the theory that osmotic stress and ion toxicity are key factors in the negative response of plants to salinity. This is consistent with the findings of Amurillo-Mudor, who stated that the addition of NaCl can decrease the yield of Aloe vera plants [16]. Moreover, the addition of NaCl can cause an imbalance of essential nutrient ions such as K^+, Ca^{2+}, and Mg^{2+}, which compete with Na^+. This nutrient deficiency can reduce the plant's ability to produce new leaves. Consequently, the reduction in the number of leaves appears to be more significant compared to other variables [17].

3.3 Impact of differences in breeder origin on growth response and yield

The analysis results indicate that the source of seedling producers significantly affects the growth and yield of aloe vera plants. This is evident in growth parameters such as plant height, leaf count, leaf area, and fresh leaf weight, as shown in Table 3. The analysis of variance for the origin of seedling producers suggests that seed sources from different producers have statistically different impacts on plant performance. This finding aligns with the theory stating that seed quality influences plant production [17].

Table 3. Results of analysis of variance in location of origin of breeders

Treatment	Average			
	Plant height (cm)	Number of leaves (Strands)	Leaf Area (cm^2)	Fresh weight of leaves (g)
P1	47.3722a	9.4458b	180.0500a	992.0833a
P2	40.4042c	8.2042c	123.9250c	473.7500c
P3	44.7545b	9.5292a	152.8333b	759.6667b

Different letter symbols in one column mean significantly different in the 5% DMRT test

P1 produced the best results for plant height, leaf area, and fresh leaf weight compared to P2 and P3. P2 generally provided the lowest results across all measured parameters. P3 ranked between P1 and P2 in terms of plant height, leaf area, and fresh leaf weight, but had a slightly higher leaf count than P1. The seedlings for P1 originated from Gunung Kidul. Overall, the seed breeders of Gunung Kidul are considered to produce seeds with better genetic quality, improved seed treatment, and superior breeding processes. As a result, these seeds yield plants that are more resilient to environmental stresses, particularly salinity stress [15, 18, 19]. The nurseries in Gunung Kidul apply better cultivation techniques, such as selecting superior parent plants and maintaining optimal growing conditions, resulting in seeds with better performance. Gunung Kidul is known for its relatively dry climate and nutrient-poor soil [21]. Plants growing in this region are likely to have developed physiological mechanisms, such as a more efficient root system or enhanced osmoregulation capabilities, making them more resistant to salinity stress and well-suited for sandy areas. Superior genetic traits can be passed on to subsequent generations, enabling Gunung Kidul seeds to maintain their advantages under various environmental conditions. Genes involved in resistance to osmotic stress and ion tolerance are more actively expressed in these seeds. This is consistent with the study by Adam et al., which stated that each variety of barley has different genetic traits in response to osmotic stress and tolerance [22]. This is in accordance with research by Rashad et al., showing that reducing soil salinity concentrations can increase growth results in soybean plants [23].

3.4 Impact of interaction between salinity stress treatment and breeder origin on growth response and yield

The growth and yield of plants are influenced by various environmental factors, one of which is soil salinity levels. Salinity stress is a major abiotic stress that can hinder water and nutrient uptake by plants, ultimately leading to decreased productivity [20]. On the other hand, the quality of seeds used, which is determined by the origin of the breeders, also plays a crucial role in determining the plant's response to salinity stress. Seeds from high-quality breeders generally exhibit better resilience to environmental stresses, including salinity [21]. Figure 6 shows the growth in the number of leaves starting from 14, 28, 32, 48 days after planting DAP.

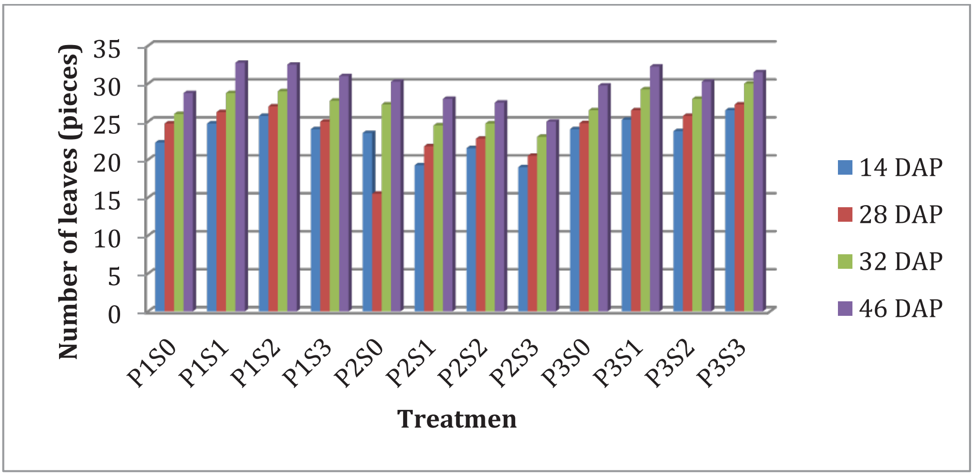


Figure 3. Observation of variable number of leaves in each treatment combination

The treatments P1S1, P1S2, P1S3, P3S1, and P3S3 showed the best results in terms of leaf count at 46 days after planting (DAP), with values approaching or reaching 30 leaves. Overall, the P1 treatment demonstrated strong performance, with P1S1, P1S2, and P1S3 consistently producing a high number of leaves over time. In contrast, the P2S0 treatment resulted in the lowest leaf count at all time points, indicating that this combination was less optimal in promoting leaf growth. This is consistent with previous findings, which indicated that P1 was a breeder; however, the addition of 20 g/L NaCl is believed to be within the tolerance limits of aloe vera plants under salinity stress [16, 22].

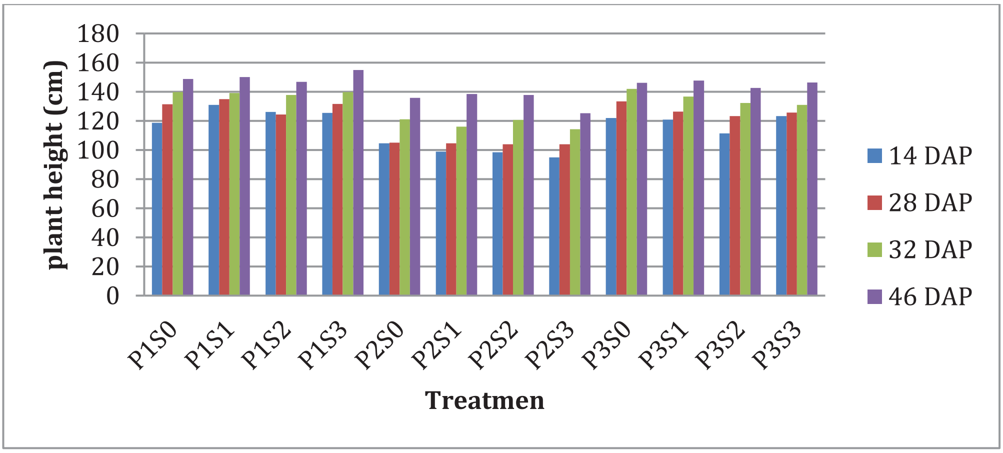


Figure 4. Observation of plant height in each treatment combination

P1S3 was the treatment that produced the best results in terms of plant height at 46 days after planting (DAP), followed by P1S0 and P1S1. Treatments in the P1 group generally showed better outcomes compared to those in the P2 and P3 groups regarding plant height. P2S0 and P2S3 had lower results in terms of plant height compared to the other treatments.

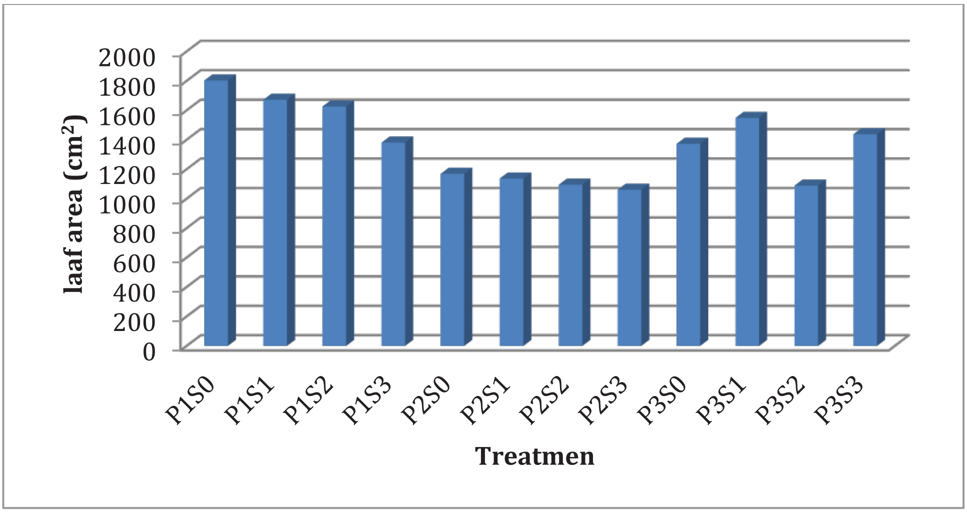


Figure 5. Observation of the results of the leaf area of the aloe vera plant

The results suggest that seeds from Gunung Kidul (P1) perform better overall, particularly in non-saline conditions (S0). However, increasing NaCl concentrations significantly reduce leaf area in all treatments, indicating the adverse effects of salinity on plant growth.

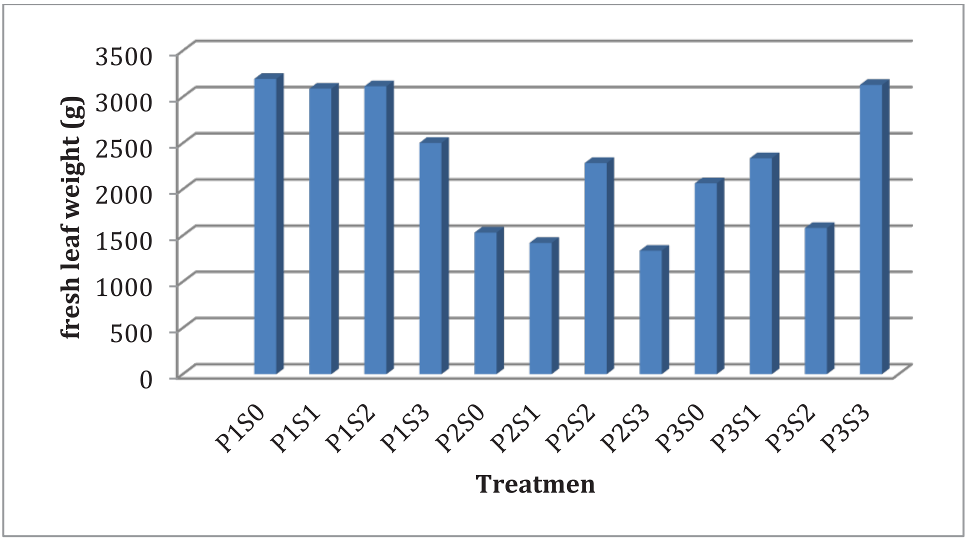


Figure 6. Observation of the results of the fresh leaf weight of the aloe vera plant

P1S0 produced the best results in terms of leaf area, followed by P1S1, P1S2, and P3S1. Generally, treatments in the P1 group provided larger leaf areas compared to those in the P2 and P3 groups, although P3S1 yielded results comparable to P1S1 and P1S2. The treatments P1S0, P1S1, P1S2, and P1S3 produced the best results in terms of fresh leaf weight, indicating that the treatments in the P1 group were able to significantly increase fresh leaf productivity. P3S3 also showed a good fresh leaf weight, nearly matching the P1 treatments, indicating that even under salinity stress, plants in this treatment were still able to produce a high fresh leaf weight. Treatments in the P2 group, particularly P2S1 and P2S2, showed the lowest fresh leaf weights, suggesting that the combination of treatments in this group was less optimal for increasing fresh leaf weight. Therefore, the P1S3 treatment has an advantage in plant growth, as it grows taller and produces more leaves, even though the leaves may be smaller. Based on the total biomass productivity results, P1S0 is superior. Although the leaf count and plant height in P1S0 are lower compared to P1S3, the larger fresh leaf weight and greater leaf area may be more beneficial in the long term for final yield.

4 Conclusion

Based on the results and discussion, it was found that each increase in NaCl concentration reduces the growth and yield of aloe vera plants. Nevertheless, the growth and yield of plants originating from breeders in Gunung Kidul showed the best values in terms of plant height, leaf count, leaf area, and fresh leaf weight. The combination of treatments from Gunung Kidul breeders without the addition of NaCl resulted in the best outcomes, although the plant height and leaf count variables from Gunung Kidul breeders with the addition of 20 g/L NaCl still demonstrated good tolerance. The recommendation for this study is to include additional physiological and biochemical observation variables, extend the harvest period, and incorporate other varieties of Aloe vera.

References

1. Dahuri R. Space Management of coastal and ocean Areas in Accrodance with Implementation of Regional Autonomy. Jurnal Mimbar. 2001;1(2).139-171.
2. Aprilia RL, Sukur S. Study Of Physical, Chemical And Biological Properties Of Sandy Soils In Some Regions Of Indonesia. Agronu Jurnal. 2022 Jul 31;1(02):71–9.
3. Anas AA, Zulfikar Z, Hisein WSA, Rahni NM, Arsyad MA, Slamet A, et al. Utilization of Backyard Land and Fermented Organic Waste as Ameliorant Materials For Food Security in Coastal Area. Jurnal Ilmiah Abdi Mas TPB Unram [Internet]. 2021 Jan 29 [cited 2024 Oct 5];3(1). Available from: http://abdimastpb.unram.ac.id/index.php/AMTPB/article/view/69
4. Auditya. Effect of Cow Manure Fertilizer Rates and Weeding Periods on Growth and Yield of Aloe vera (Aloe chinensis B.) and Sesame (Sesamum indicum L.) in Intercropping System in Coa. Vegetalika. 2015;4:46–55.
5. Rahardian. Pengaruh Takaran Pupuk Kandang dan Interval Penyiraman Terhadap Pertumbuhan Lidah Buaya (Aloe chinensis Baker) di Lahan Pasir Pantai Keburuhan Purworejo. Fakultas Pertanian; 2011; 3
6. Hastilestari BR. Kajian plastisitas sistem fotosintesis pada tanaman CAM. Proseding Seminar Nasional Masyarakat Biodeversitas Indonesia. 2015; 1(4):864-867 [cited 2024 Oct 5]. Available from: http://biodiversitas.mipa.uns.ac.id/M/M0104/M010436.pdf
7. Radian. The Effect of Various Types of Soil and Marine Mud on the Growth and Yield of Aloe Vera as a Phytopharmaceutical Plant. Jurnal Kesehatan Kathulistiwa. 2017;3(1):430–44.
8. Darini MT. The Influence of Integrated Fertilizer on Physiological and Agronomic Character of Aloe Vera L. Faculty of Agriculture, Universitas Sarjanawiyata Tamansiswa,Yogyakarta, Indonesia,Plant in Sandy Soil. International Jurnal Curr Sci Res [Internet]. 2020 Dec 31 [cited 2024 Oct 5];03(12). Available from: https://ijcsrr.org/single-view/?id=3360&pid=3267
9. Murillo-Amador B, Córdoba-Matson MV, Villegas-Espinoza JA, Hernández-Montiel LG, Troyo-Diéguez E, García-Hernández JL. Mineral Content and Biochemical Variables of Aloe vera L. under Salt Stress. Gaquerel E, editor. PLoS ONE. 2014 Apr 15;9(4):e94870.
10. Jumini. Pengaruh Jenis Pupuk Organik dan Jarak Tanaman. Jurnal Floratek. 2006; (2): 107-113
11. Puteri DR, Ulpah S, Maizar M. Respon Tanaman Lidah buaya (Aloe vera mill) Terhadap Beberapa Jenis Pupuk Organik. Dinas Pertanian. 2019 Sep 23;33(1):69–74.
12. Djukri. Cekaman Salinitas Terhadap Pertumbuhan Tanaman. Proseding Seminar Nasional Penelitian dan Pendidikan Penerapan MIPA. 2009; Available from: https://core.ac.uk/download/pdf/33509898.pdf
13. Yurisinthae E, Dolorosa E, Muani A. Analisis Faktor-faktor yang mempengaruhi Produksi Usaha Tanai Lidah Buaya di Sentra Produksi Kota Pontianak Propinsi Kalimantan. Jurnal Ilmu Pengetahuan dan Rekayasa. 2012; 1: 18-26
14. Kusumawaty Y, Edwina S, Maharani E. Analisis Efesiensi Tanaman Lidah Buaya di Kelurahan Maharatu Kecamatan Marpoyan Damai Kota Pekan baru. Jurnal Agribisnis. 2018 Jul 24;20(1):85–97.
15. Silva H, Sagardia S, Seguel O, Torres C, Tapia C, Franck N, et al. Effect of water availability on growth and water use efficiency for biomass and gel production in Aloe Vera (Aloe barbadensis M.). Industrial Crops and Products. 2010 Jan;31(1):20–7.

16. Murillo-Amador B, Nieto-Garibay A, Troyo-Diéguez E, García-Hernández JL, Hernández-Montiel L, Valdez-Cepeda RD. Moderate salt stress on the physiological and morphological traits of Aloe vera L. Botani Sciences. 2015 Sep 14;93(3):639–48.
17. Imran S, Sarker P, Mahamud MdA, Paul NC, Chakrobortty J, Harine IJ, et al. Copper mitigates salinity stress by regulating water status, photosynthetic pigments and ion homeostasis and increases the yield of Eggplant (Solanum melongena). BMC Plant Biology. 2024 Oct 5;24(1):927.
18. savage. Influence of Seed Quality on Crop Establishment, Growth, and Yield [Internet]. 1 st Edition. CRC Press; 1995. 24 p. Available from: https://www.taylorfrancis.com/chapters/edit/10.1201/9781003075226-11/influence-seed-quality-crop-establishment-growth-yield-finch-savage
19. Waman. Salinity Tolerant Tropical and Subtropical Crops of Horticultural Importance: an Overview. Vegetos. 2016;29:33–41.
20. Elena. Responses of Medicinal Plants to Abiotic Stresses. 4th ed. Vol. 2. 2019. 41 p.
21. Mulyadi M. Peran Pemerintahan dalam Mengatasi Pengangguran dan Kemiskinan dalam Masyarakat. Jurnal Kajian . 2016;21(3). 221-236.
22. Adem GD, Roy SJ, Zhou M, Bowman JP, Shabala S. Evaluating contribution of ionic, osmotic and oxidative stress components towards salinity tolerance in barley. BMC Plant Biology. 2014 Dec;14(1):113.
23. T. Rashad R, Shaban KAH, Ashmaye SH, Abd El-Kader MG, Mahmoud AA. Effect of pre-sowing magnetic treatment of seeds with bio- and mineral fertilization on the soybean cultivated in a saline calcareous soil. Sains Tanah - Jurnal Soil Scince Agroclimatology. 2022 Jul 15;19(2):132.
24. Syvertsen JP, Garcia-Sanchez F. Multiple abiotic stresses occurring with salinity stress in citrus. Environmental Experiment Botani. 2014 Jul;103:128–37.
25. Ashraf M, Wu L. Breeding for Salinity Tolerance in Plants. Critical Reviews Plant Sciences. 1994 Jan;13(1):17–42.
26. Arshad Ullah M, Rasheed M, Mahmood IA. Aloe vera (Aloe barbadeenis mll) screens at suitable salinity and sodicity level. Horticultura International Jurnal [Internet]. 2018 Dec 6 [cited 2024 Oct 17];2(6). Available from: https://medcraveonline.com/HIJ/aloe-vera-aloe-barbadeenis-mll-screens-at-suitable-salinity-and-sodicity-level.html
27. Imran S, Sarker P, Mahamud MdA, Paul NC, Chakrobortty J, Harine IJ, et al. Copper mitigates salinity stress by regulating water status, photosynthetic pigments and ion homeostasis and increases the yield of Eggplant (Solanum melongena). BMC Plant Biology. 2024 Oct 5;24(1):927.