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IMPACT OF SALINE ENVIRONMENT ON THE GROWTH AND PERFORMANCE OF WATER HYACINTH (EICHHORNIA CRASSIPES) (PONTEDERIALES; PONTEDERICEAE)

Faton Manhognon Oscar Eulogе[1], Montcho Hambada Koffi David[2] , Bonou-Gbo Zaki[3], Hamit Mangare Agoure[4], Djedatin Gustave[5], Fanou Lucie[6], Ayi Théophane[7], Gnancadja-Andre Léopold Simplice[8]

[1,3,4,8]Laboratory of Plant Physiology and Study of Environmental Stresses: Research Unit in Phytopathology and Plant Protection/ UAC/ FAST/ BENIN

[2]Laboratory of Plant, Horticultural and Forest Sciences UNA/BENIN

[3]Laboratory of Biotechnology, Genetic Resources and Animal and Plant breeding UAC/FAST/BENIN

[3,5]Laboratory of Molecular Biology and Bioinformatic Applied to Genomic/UNSTIM/ ENSBBA/BENIN

[6,7]Laboratory of Food Technology and Quality Control /UATM GASA-Formation

ABSTRACT

Water hyacinth is a floating macrophyte aquatic plant from the family Pontederiaceae, growing on the surface or in in land waterways. Its proliferation impacts significantly on ecosystems, but also on populations and their economic activities, giving rise to disastrous effects on agriculture, fishing, electricity production, transport, public health, means subsistence, and living conditions. The objective of this research is to study the effect of a saline environment on the growth parameters of water hyacinth to limit its proliferation. To achieve this, water hyacinth seedlings were collected from Sô-Ava, Beninfor evaluation in a controlled environment by using different concentrations of the medium in salt. Growth parameters of water hyacinth were measured on the leaves, the stem, and the roots. Statistical analyses were therefore carried out with R software and Excel 2016 for descriptive statistics, analysis of variance, and construction of graphs. Through this evaluation doses of saline concentration evaluated allow us to conclude that water hyacinth could tolerate a maximum salt concentration of 0.062 mol.L^{-1}. At a saline concentration of 0.248 mol.L^{-1} of the culture medium, the plant can no longer perform its metabolic functions and dies two weeks after treatment. However, an average concentration of 0.124 mol.L^{-1} of the medium in salt considerably limited the growth of the plants. Given these results, it is necessary to research the impact of this salt concentration on other living beings in the lagoon ecosystem to propose an effective fight against water hyacinth.

KEYWORDS: *Ecosystem, Eichhornia Crassipes, Environment, Salt Tolerance, Proliferation.*

Article History

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INTRODUCTION

Water hyacinth (*Eichhornia crassipes)* is a floating macrophyte aquatic plant in the family Pontedericeae, growing on the surface or in the mud of waterways. It is native to Latin America where it lives in symbiosis in the aquatic ecosystem. *Eichhornia Crassipes*, introduced in Africa at the end of the year 1800 (Center *et al*., 2002), appears today as the most invasive aquatic plant, and of great concern throughout the continent where it constitutes a real threat for streams, lakes, and rivers (Hill and Coetzee, 2008). Water hyacinth proliferation' has significant impacts on ecosystems, but also on populations and their economic activities, giving rise to devastating effects on agriculture, fishing, electricity production, transport, public health, livelihoods, and living conditions (Hussain et al., 2016; Rutabagaya, 2017; Honlah et al., 2019). Due to its ecological and socio-economic impacts, it is one of the 100 most harmful invasive species in the world. Thanks to its height and high density, the plant can reduce light and oxygen under water. This strangling of underwater life affects the balance of the aquatic ecosystem. Although, the origin of hyacinth infestation worldwide began in the early 20thcenturyis known, that its current expansion is poorly understood. During the last ten years, its rapid spread in tropical and subtropical Africa has been favored by the state of advanced eutrophication of watercourses. This phenomenon of eutrophication is caused by the excessive supply of nitrogen and phosphorus nutrients from wastewater of domestic, agricultural, or industrial origin which causes ecological and hydro-agricultural crises (Faton et al., 2016). In West Africa, particularly in Benin where it is called " Togle ", these invasive species alter the functioning of aquatic ecosystems by threatening fisheries, river transport, docking, tourism, and even human health because it offers a favorable environment for snails and mosquitoes carrying schistosomiasis, malaria and other diseases (Fiogbé, 2011). By preventing the penetration of solar radiation, the dense carpet of hyacinth decreases the photosynthesis of the primary producers at the base of the food chains. The decomposition of dead leaves createsan environment anoxic, limiting oxygen for the environment's species, thus leading to the eutrophication of the water frame (Kpondjo, 2008; Guézo et al., 2022). This situation alters the physico-chemical and organoleptic quality of the water and then reduces fishing stocks.

The sustainable management of hyacinth infestation has focused on several control methods including physical removal, biological control, and the chemical method. The methods traditionally used are expensive, and sometimes complex to implement. They are not always effective and can have undesirable impacts on the environment (Pieterse et *al.*, 1996). The disadvantages of commonly used means of control have encouraged the search for other more sustainable methods. Physical struggle is an expensive method; chemical control is a method that has consequences on the environment while biological control is a method that involves the mass rearing and release of natural enemies, at a high cost.

Indeed, populations living in localities like Sô-Ava suffer from the large-scale multiplication of water hyacinth. Salinity is one of the factors that influences the growth of these plants in the estuarine zone. Much research has shown that sodium chloride (NaCl) is likely to affect the growth, and therefore the survival, of invasive aquatic plants (*Salvinia molesta*, *Pistia Stratiotes,* and *Eichhornia crassipes*) (Egnankou and *al* ., 2016). However, these various studies are more focused on saline intrusion, as was the case in Côte d'Ivoire where the increase in water salinity by the opening of the Comoe River pass at Grand-Bassam caused the mortality of hyacinth plants before their evacuation to the Atlantic Ocean. This operation led to hydrological, sedimentary, and ecological changes in the lagoon area near the pass, creating a new estuarine area. Nevertheless, since this species has an incompatibility with sodium chloride, spray control methods have been considered and successfully tested against its development (Guézo et *al.*, 2022) to minimize the negative effects that

the increase in salinity could generate, both on living beings and on the hydrology and ecology of infested water bodies.

The objective of this research is to determine the salt concentration of the medium limiting the growth of water hyacinth (*Eichhornia crassipes*).

MATERIAL AND METHODS

Presentation of the Study Environment

Located in Benin, in the department of Atlantic, the municipality of Sô-Ava occupies the lower valley of the Oueme river and the Sô river to which it owes its name. With a population of 86,315 inhabitants and an area of 218 km² (RGPH, 2012), Sô-Ava is between 6°25 and 6°39 North latitude, 2 °21 and 2°30 East longitude. It is limited at the north by the communes of Ze, Dangbo and Adjohoun; at the south by the commune of Cotonou; at the east by the commune of Aguegues and at the west by the commune of Abomey-Calavi. The main ethnic groups in the commune of Sô-Ava are the toffins with the local presence of ouemenous. In the population, they are catholicism (22.5%), traditional religion (22.1%), protestantism (8.3%), muslim religion (5.3%), and other (37.8 %). The main income-generating activities practiced are market gardening and fish farming (in ponds, floating cages, as well as acadjas) (Kinsiclounon et *al.,* 2013).

During the rainy season, the proliferation of water hyacinth becomes a major problem for the population living in this area. The climate is subtropical, characterized by a long rainy season (between mid-March and mid-July), a short dry season (between mid-July and mid-September), a short rainy season (between mid-September and mid-November), and a long dry season (between mid-November and mid-March).

Sampling of Young Seedlings by *Eicchornia Crassipes*

Different water hyacinth proliferation sites were chosen for the collection of seedlings on the orientation of the guide on the Sô river located in the commune of Sô-Ava. Samples of 200 young seedlings were taken and kept in containers during their transport to the experimental site. Seedlings showing no symptoms of the disease were identified and sampled.

Evaluation of Plants in a Saline Environment

Before setting up the experimental design, seedlings were cleaned to remove the organic waste as well as the aphides that had taken refuge there. Thus, a total of 150 seedlings were sorted and the first measurements were taken before their transfer to the culture medium. The design consists of 6 treatments arranged in Fisher blocks. Each block consisted of 6 treatments each representing an experimental unit. Each unit consisted of 5 water hyacinth seedlings placed in a total water solution of 5L. Each treatment was enriched with an application of 40 g of poultry manure three weeks after installation of the design. Knowing that the concentration of seawater in salt is 36.5g/L (Benmoussat and Habi, 2014), different dilutions were carried out with running water from the National Water Company of Benin (SONEB). Thus, medium 1 (M1) was only tap water and represented the negative control (absence or slight salt concentration). Medium 2 (M2), 3 (M3), 4 (M4) and 5 (M5) consisted of a mixture of tap water and seawater. For a total volume of 5L per bucket, the quantity of seawater used in these treatments was respectively 0.5 L; 1L; 2 L and 3 L. The last medium (M6) consisted exclusively of 5 L of seawater and used as a positive control (high saline concentration of the medium).

Data Collection, Processing and Analysis

Plant growth parameters considered were leaf length (LL), number of leaves per plant (NLP), number of dead leaves (NDL), petiole length (PL), stem length (SL), petiole diameter (PD) and root length (RL). Measurements were taken each week on 2 plants per experimental unit according to each medium, i.e. a total of 10 plants were considered for data collection per treatment.

The data collected were recorded and processed using Excel 2016 spreadsheet and then subjected to various statistical analyzes such as descriptive statistics and analysis of variance (ANOVA) according to the Student Newman Keuls test carried out with R4.2.1 software. Then pie chart and histogram were built with Excel 2016 spreadsheet.

RESULTS

Analysis of the Distribution of Variables during the Different Treatments

The analysis of the distribution of the different variables taken during the evaluation of the water hyacinth in saline conditions shows a variability at the level of all the variables (**Table 1**). Thus, large variations were recorded with root length (RL) for an average value of 11.12 ± 5.988 cm; the number of leaves (NL) with an average value of 5.64 ± 3.329 cm; the number of dead leaves (NDL) for an average of 1.93 ± 2.508 cm and the stem length (SL) with an average of 4.33 ± 1.099 cm. Finally, according to the analysis of the coefficients of variation, there is a wide distribution around the means obtained for the different variables. The greatest variation of 59.02% is obtained with the number of leaves variable (NL) while the lowest is recorded with the leaf length (LL) and stem length (SL) variables for respective values of 25%, 26% and 25.38%.

Table 1: Descriptive Statistics of the Different Variables Measured

	Mean	Minimum	Maximum	CV(%)	Standard deviation
LF (Cm)	3.10	0.77	4.53	25.26	0.783
RL(Cm)	11.12	3.33	26.67	53.85	5.988
NL	5.64	0.67	15.67	59.02	3.329
SD (cm)	1.58	0.37	2.63	26.33	0.416
SL(cm)	4.33	2.01	7.82	25.38	1,099
PL(cm)	1.09	0.36	2.48	35.69	0.389
NDL	1.93	0.00	11.33	53.47	1.032

LL: Leaf Length; RL: Root Length; NL: Number of leaves; SD: Stem Diameter; SL: Stem Length; PL: Petiole length; NDM: Number of Dead Leaves; Cm: Centimeter; CV: Coefficient of variation; %: percentage.

Analysis of Variance of Measured Parameters

Analysis of variance (ANOVA) was carried out to measure the significance of the difference which would exist between the various parameters during the various weeks of evaluation. Performed with the Student Newman Keuls test at a probability of 5%, different significance levels were obtained (**Table 2**). A total of six media were applied and the evaluation lasted 5 weeks including a buffer week called S0. During this buffer week when all the plants were put under the same conditions by using a freshwater solution, the analysis of the data shows that there is no significant difference between the media for each of the evaluated traits (**Table 2a**). No dead leaves were recorded during this first evaluation period.

Different observations were made from the first week of the evaluation (S1) through the variation of culture media by the use of seawater. However, no significant difference between LL, PL, and NDL for the six different treatments is obtained after this first week of evaluation (**Table 2a**). Thus, only RL, NL, SD, and SL showed significant differences for the six parameters with specificities. The uses of medium T1 (0 mol.L $^{-1}$) show significant differences from each of the other media with variable salt concentration for the four above-mentioned variables. Moreover, considering the media with a saline concentration, significant differences were obtained between that having 0.062 mol.L $^{-1}$ (M2) and each of the four other media for RL and SL. Finally, variations obtained with these traits for M3 (0.124), M4 (0.248), M5 (0.372), and M6 (0.62) are not linked to the differences in saline concentrations of the culture medium.

Table 2a: Analysis of Variance of the Measured Trait during the First 2 Weeks of Assessment

	Traits	M1	M2	M3	M4	M5	M6
S0	LL	3.45±0.345^{a}	2.67±0.380^{a}	3.20±0.603^{a}	2.88±0.712^{a}	2.93±0.598^{a}	3.68±0.837^{a}
	RL	5.33±0.333^{a}	5.78±2.694^{a}	4.83±0.866^{a}	4.78±1.711^{a}	4.94±0.788^{a}	4.77±0.509^{a}
	NL	4.78±0.770^{a}	3.44±0.385^{a}	3.56±0.509^{a}	3.33±0.577^{a}	4.44±0.385^{a}	4.11±0.694^{a}
	SD	1.84±0.108^{a}	1.57±0.157^{a}	1.75±0.314a	1.45±0.271^{a}	1.61±0.20a	1.81±0.137^{a}
	SL	4.02±0.5591^{a}	4.31±0.413^{a}	4.35±0.667a	3.81±0.267^{a}	4.68±0.632^{a}	4.65±0.396^{a}
	PL	1.09±0.089^{a}	1.13±0.254^{a}	0.93±0.275a	1.39±0.944^{a}	0.74±0.136^{a}	0.84±0.148^{a}
	NDL	0	0	0	0	0	0
S1	LL	3.69±0.500^{a}	3.21±0.438^{a}	3.47±0.493^{a}	2.97±0.170^{a}	3.08±0.121^{a}	3.49±0.246^{a}
	RL	16.66±1.826^{a}	9.14±4.001^{ab}	12.21±5.236^{b}	7.71±1.230^{b}	8.99±0.864^{b}	8.96±1.019^{b}
	NL	8.67±3.383^{a}	5.44±0.385^{b}	5±0.333b	4.67±0^{b}	5.78±0.509^{b}	5.22±0.192^{b}
	SD	2.29±0.023^{a}	1.69±0.112^{b}	1.68±0.097^{b}	1.69±0.239^{b}	1.83±0.189^{b}	1.87±0.081^{b}
	SL	4.47±0.724^{a}	3.43±0.181^{ab}	3.42±0.188^{b}	3.45±0.152^{b}	3.68±0.179^{b}	4.09±0.134^{b}
	PL	1.67±0.287^{a}	1.16±0.111^{a}	1.18±0.078^{a}	1.24±0.2216^{a}	1.29±0.291^{a}	1.29±0.301^{a}
	NDL	1.22±0.694^{a}	0.67±0.577^{a}	0.89±0.694^{a}	0.44±0.192^{a}	0.56±0.509^{a}	0.22±0.192^{a}

LL: Leaf length; RL: Root Length; NL: Number of Leaves; SD: Stem Diameter; SL: Stem Length; PL: Petiole length; NDL: Number of Dead Leaves; M1: 0 mol.L^{-1} of NaCl; M2: 0.062 mol.L^{-1} of NaCl; M3: 0.124 mol.L^{-1} of NaCl; M4: 0.248 mol.L^{-1} of NaCl; M5: 0.372 mol.L^{-1} of NaCl ; M6: 0.62 mol.L^{-1} of NaCl ; S0: Buffer Week; S1: First week after evaluation.

From the second week after starting evaluation (S2), the plants in culture in media M4, M5 and M6 died, thus leading to the absence of data in table 2b. However, significant differences were observed between the three remaining media (**Table 2b**). The three media showed no significant difference for RL, SD, and PL. From the differences obtained, M1 is significantly different from the other two media (M2 and M3) for LL, NL and NDL. As for the length of the Rods (SL), M1 and M2 did not generate any significant difference. Only the evaluation of the medium M3 made it possible to obtain a significant difference compared to the other two.

At three weeks after dosing the media with the saline solution at different concentration levels, no significant difference is obtained between the three media for the DT variable. The M1 medium is also significantly different from the others for the six other measured variables such as LL, RL, NL, PL, SL, and NDL. In addition, a significant difference is obtained between M2 and M3 for the NDL variable (**Table 2b**).

At one month after application, ie S4, no significant difference is observed between the three media for variables such as RL, DT and PL. Thus, the variables LL, NL, SL, and NDL indicated significant differences related to culture media. M1 is then significantly different from the other two (M2 and M3) (**Table 2b**).

Table 2b: Analysis of Variance of the Variables Measured during the Last 3 Weeks of Assessment

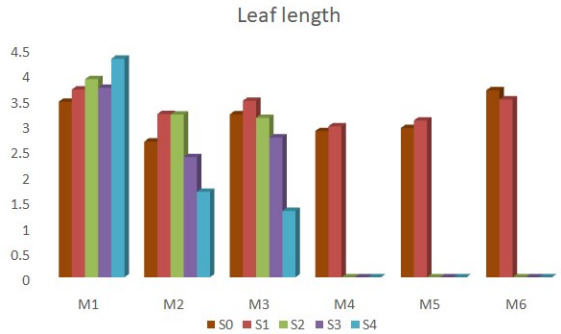
	Traits	M1	M2	M3
S2	LL	3.89±0.173^{a}	3.20±0.157^{b}	3.13±0.369^{b}
	RL	20.87±5.051^{a}	17.56±2.949^{a}	12.533±5.499^{a}
	NL	10.33±0.881^{a}	6.56±2.795^{b}	3.89±1.072^{b}
	SD	1.52±0.111^{a}	1.82±0.032^{a}	1.492±0.335^{a}
	SL	5.12±0.230^{a}	4.26±0.188^{a}	2.98±0.928^{b}
	PL	1.39±0.178^{a}	1.06±0.051^{a}	1.06±0.479^{a}
	NDL	1.11±0.769^{b}	3.33±1.202^{a}	4±0.333^{a}
S3	LL	3.73±0.253^{a}	2.36±0.306^{b}	2.75±0.382^{b}
	RL	23.22±1.347^{a}	10.33±1^{b}	9.44±1.575^{b}
	NL	13.44±1.018^{a}	4.67±2.027^{b}	2.11±0.385^{b}
	SD	1.32±0.543^{a}	1.28±0.152^{a}	1.29±0.069^{a}
	SL	6.01±1.095^{a}	3.57±0.218^{b}	3.69±0.906^{b}
	PL	1.26±0.131^{a}	0.56±0.098^{b}	0.52±0.078^{b}
	NDL	2.22±0.769^{b}	3.56±0.509^{ab}	4.22±0.839^{a}
S4	LL	4.29±0.221^{a}	1.68±0.719^{b}	1.30±0.547^{b}
	RL	18.89±1.388^{a}	13.14±1.098^{a}	13.49±4.910^{a}
	NL	12.78±3.422^{a}	3.33±1.453^{b}	1.89±1.171^{b}
	SD	1.83±0.837^{a}	0.97±0.34^{a}	0.69±0.347^{a}
	SL	7.55±0.236^{a}	4.54±0.655^{b}	4.86±1.032^{b}
	PL	1.35±0.311^{a}	0.79±0.374^{a}	0.84±0.443^{a}
	NDL	2.33±0.577^{b}	7.89±3.501^{a}	7.78±1.071^{a}

LL: Leaf length; RL: Root Length; NL: Number of Leaves; SD: Stem Diameter; SL: Stem Length; PL : Petiole length; NDL: Number of Dead Leaves; M1: 0 mol.L $^{-1}$ of NaCl ; M2: 0.062 mol.L $^{-1}$ of NaCl ; M3: 0.124 mol.L $^{-1}$ of NaCl ; M4: 0.248 mol.L $^{-1}$ of NaCl ; M5: 0.372 mol.L $^{-1}$ of NaCl ; M6: 0.62 mol.L $^{-1}$ of NaCl; S2: Second week after evaluation; S3: third week after evaluation; S4: fourth week after evaluation.

Average Evolution of the Different Variables during the Treatments

Leaf Length

For all the evaluations, the different salt concentrations of the media with saline water were carried out one week after the setting up of the experimental design. Thus, during the screening period with simple tap water (C = 0 mol.L^{-1}), the length of the leaves presented increasing average values throughout the experiment with values between 3.45 cm and 4.30 cm. With M2 media (0.062 mol.L^{-1} (M2) and M3 (0.124 mol.L^{-1}), this length considerably decreased since the first week with respective average values of 3.21 cm to 1.68 cm and 3.47 cm to 1.30 cm. However, a higher concentration of the medium in salt (M4, M5, and M6) caused the death of the plants.

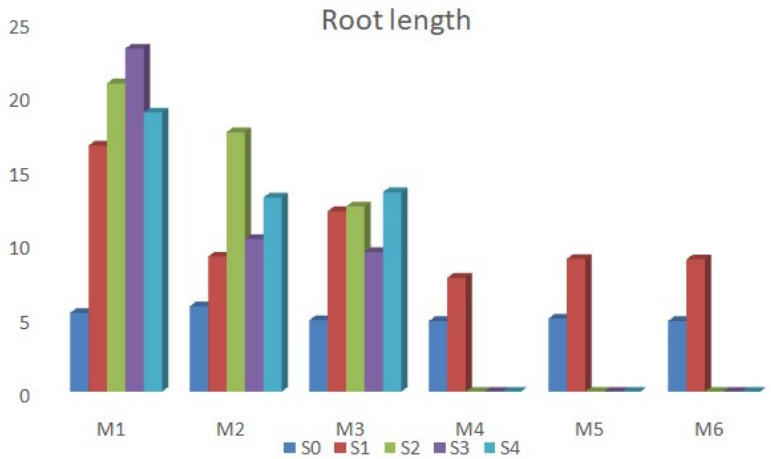


M1: 0 mol.L- ^{1} ; M2: 0.062 mol.L $^{-1}$; M3: 0.124 mol.L $^{-1}$; M4: 0.248 mol.L $^{-1}$; M5: 0.372 mol.L $^{-1}$; M6: 0.62 mol.L $^{-1}$; S0: buffer week without variation of environment; S1: one week after treatment; S2: two weeks after treatment; S3: three weeks after treatment; S4: four weeks after treatment.

Figure 1: Evolution of Leaf Length at the Level of the Six Treatments.

Root Length

From week S0 to week S1 for all the media, the plant roots exhibited significant growth with average values between 4.78 cm (M4 and M6) and 5.78 cm (M2). This growth evolved until the third week after treatment (23.22 cm) before decreasing to an average value of 18.89 cm for the M1 medium. After good root growth, despite their evaluation in M2, there was a considerable decrease in the length of the roots in the third week (10.33 cm) before progressing to an average value of 13.14 cm in the fourth week. Finally, a similar evolution as for the second medium was observed with the third medium decreasing from an average value of 12.53 cm (S2) to 9.44 cm (S3) to increase to an average value of 13.50 cm (S4) (**Figure 2**).

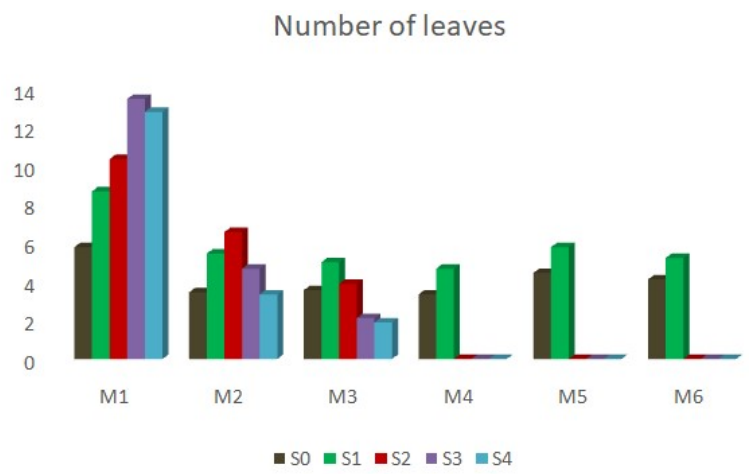


T1: 0 mol.L- [1]; T2: 0.062 mol.L $^{-1}$; T3: 0.124 mol.L $^{-1}$; T4: 0.248 mol.L $^{-1}$; T5: 0.372 mol.L $^{-1}$; T6: 0.62 mol.L $^{-1}$; S0: buffer week without variation of medium; S1: one week after treatment; S2: two weeks after treatment; S3: three weeks after treatment; S4: four weeks after treatment.

Figure 2: Variation in Root Length Across the Six Treatments.

Number of Leaves

The appearance of new leaves was noticed in all six media between the evaluation periods S0 and S1. Plants continued to set new leaves with M1 for mean values of 8.67 leaves from S1 to 13.44 leaves at S3. A slight loss of leaves was also observed in the fourth week to reach an average value of 12.78 leaves. This trait also showed an increasing growth between the first week (5.44 leaves on average) and the second week (6.56 leaves on average) before relapsing until the fourth week (3.33 leaves on average) for the medium having a saline concentration of 0.062 mol.L $^{-1}$ (M2). Unlike the previous two Medium, Medium M3 showed a decrease in leaf count as early as the second week after application (**Figure 3**).

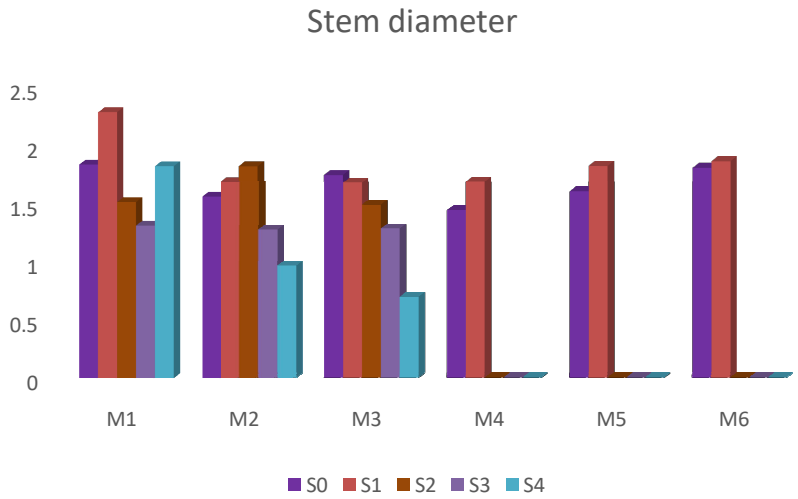


M1: 0 mol.L- ^{1} ; M2: 0.062 Mol.L $^{-1}$; M3: 0.124 mol.L $^{-1}$; M4: 0.248 mol.L $^{-1}$; M5: 0.372 mol.L $^{-1}$; M6: 0.62 mol.L $^{-1}$; S0: buffer week without variation of environment; S1: one week after treatment; S2: two weeks after treatment; S3: three weeks after treatment; S4: four weeks after treatment.

Figure 3: Variation in the Number of Leaves at the Level of the Six Treatments.

Stem Diameter

At the first level of evaluation, analysis shows an increase of stem diameter after the first week of application (2.29 cm on average) followed by a decrease from the second week to an average value of 1, 32 cm at the third. It finally increased between the third and fourth week after application (1.83 cm on average). However, from an average value of 1.57 cm during the buffer week (S0), M2 induced an increase in diameter until the second week (1.82 cm) before gradually decreasing to an average value of 0.97 cm in the fourth week. At a higher medium saline concentration (M3), and with an initial average value of 1.75 cm, a reduction in diameter is noted from the first week to an average value of 0.70 cm after four weeks (**Figure 4**).

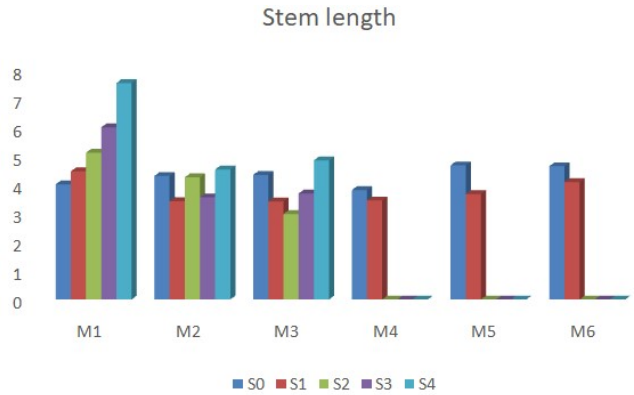


M1: 0 mol.L- ^{1}; M2: 0.062 mol.L $^{-1}$; M3: 0.124 mol.L $^{-1}$; M4: 0.248 mol.L $^{-1}$; M5: 0.372 mol.L $^{-1}$; M6: 0.62 mol.L $^{-1}$; S0: buffer week without variation of environment; S1: one week after evaluation; S2: two weeks week after evaluation; S3: three weeks after evaluation: S4: four weeks after evaluation.

Figure 4: Variation in the Diameter of the Stems at the Level of the Six Treatments.

Stem Length

Water hyacinth evaluation in medium M1 (0 mol.L $^{-1}$) shows an exponential evolution of the stem length during the five weeks of screening. However, a saw tooth evolution was observed for this same variable with M2 for mean values between 3.43 cm (S1) and 4.54 cm (S4). Compared to S0 with M3, the length of the stem increased extremely in the fourth week. Media M4, M5, and M6 also induced a reduction in stem length from S0 to S1 (**Figure 5**).

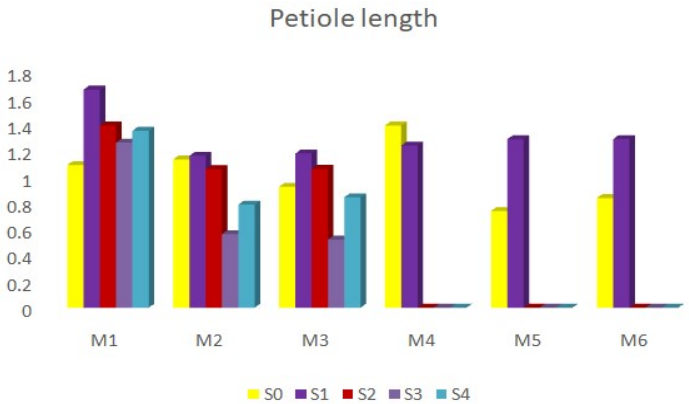


M1: 0 mol.L- ^{1} ; M2: 0.062 mol.L $^{-1}$; M3: 0.124 mol.L $^{-1}$; M4: 0.248 mol.L $^{-1}$; M5: 0.372 mol.L $^{-1}$; M6: 0.62 mol.L $^{-1}$; S0: buffer week without variation of environment; S1: one week after evaluation; S2: two weeks week after evaluation; S3: three weeks after evaluation: S4: four weeks after evaluation

Figure 5: Variation in the Length of the Stems at the Level of the Six Treatments.

Petiole Length

Petiole length shows a different evolution from one medium to another. With M1, this length increased from an average value of 1.09 cm (S0) to 1.67 cm (S1) before being reduced to a final value of 1.35 cm in the fourth week. (S4). The greatest lengths were obtained with M2 between weeks S0 (1.13 cm), S1 (1.16 cm), and S2 (1.06 cm). This length was further reduced after the third week to 0.56 cm before increasing to 0.79 cm. M3 medium produced the greatest lengths after the first (1.18 cm) and second (1.06 cm) weeks reaching a final value of 0.84 cm at the fourth week. Except for medium M4, where petiole length decreased, it considerably increased in medium M5 and M6 between weeks S0 and S1 (**Figure 6**).

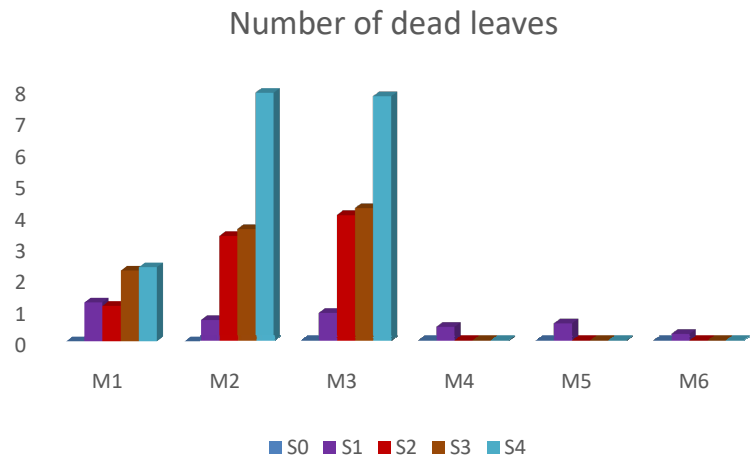


M1: 0 mol.L- ^{1} ; M2: 0.062 mol.L $^{-1}$; M3: 0.124 mol.L $^{-1}$; M4: 0.248 mol.L $^{-1}$; M5: 0.372 mol.L $^{-1}$; M6: 0.62 mol.L $^{-1}$; S0: buffer week without variation of medium; S1: one week after evaluation; S2: two weeks week after evaluation; S3: three weeks after evaluation: S4: four weeks after evaluation.

Figure 6: Variation in the Length of the Petiole at the Level of the Six Treatments.

Number of Dead Leaves

The saline environment affects the viability of the leaves. Thus, for each of the medium, no loss of leaves was observed during week S0. For a maximum average value of 2.33 dead leaves with medium M1 during the screening period, this number increases with the salt concentration evaluated during culture in the 5 other media to reach a maximum average value of 7.89 dead leaves (M2). The death of the plants two weeks after the treatment thus did allow to evaluate this trait with M4, M5, and M6 (**Figure 7**).



M1: 0 mol.L- ^{1} ; M2: 0.062 mol.L $^{-1}$; M3: 0.124 mol.L $^{-1}$; M4: 0.248 mol.L $^{-1}$; M5: 0.372 mol.L- ^{1} ; M: 0.62 mol.L- ^{1} ; S0: buffer week without variation of environment; S1: one week after evaluation; S2: two weeks week after evaluation; S3: three weeks after evaluation: S4: four weeks after evaluation.

Figure 7: Variation in the Number of Dead Leaves at the Level of the Six Treatments.

Impacts of the Saline Environment on the Growth of Water Hyacinth

The impact of the saline environment on the performance of the different traits was evaluated. Whatever the traits, salt's presence in the culture medium of water hyacinth hurt its growth. Thus, with a medium salt concentration of 0.062 mol.L $^{-1}$ (M1), the stem diameter had less impact with a reduction of 16.78% while the greatest impact was found with the number of dead leaves (55.45% loss). Medium with a double salt concentration of 0.124 mol.L $^{-1}$ (M2), showed more impact on the various traits and led to a loss of performance ranging from 21.49% (SD) to 67.76% (NL).

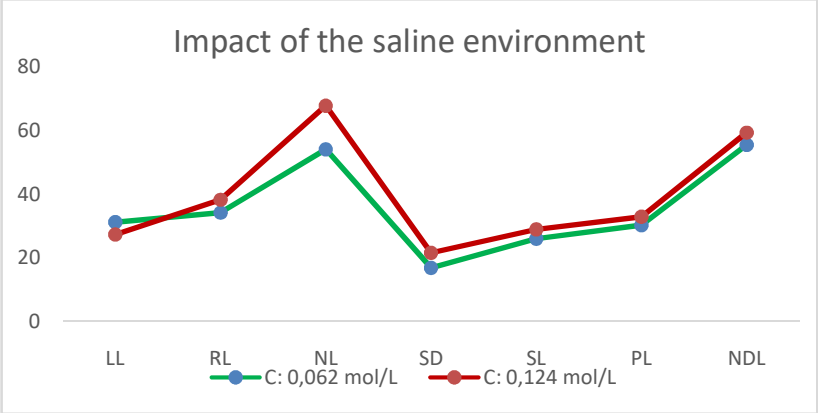


Figure 8: Impact of Salt Concentration on Water Hyacinth Growth.

DISCUSSION

The water hyacinth is a species of monocotyledonous plant of the Pontederiaceae family whose growth is the fastest in the plant kingdom. It has thick, glossy leaves with bulbous, spongy roots measuring up to 6 centimeters in diameter and 30 centimeters length. These characteristics give this floating aquatic plant tremendous strength and resistance, making life difficult for local residents. In Benin, according to Faton et *al.,*(2016), this plant has been the subject of little study while it proliferates in the various wetlands, in particular the Sô river in the commune of Sô-Ava and its surroundings (Faton et *al.,* 2016). Because of its height and high density, it reduces light and oxygen underwater (Dogno et al.; 2007), which will result in the suffocation of animals such as fish and other species (Fiogbe, 2011). To overcome these problems, different control methods have been highlighted by Faton (2016) against water hyacinth. In Africa, according to Guézo et *al*., (2022), the fight against water hyacinth with salt was carried out by increasing the salinity of the water as in Côte d'Ivoire for example thanks to the opening of the Comoé river pass in Grand -Bassam (Guézo et *al.*, 2022). The latter caused the mortality of water hyacinth plants before their evacuation to the Atlantic Ocean. But, this method has had adverse consequences on the aquatic, sedimentary, and ecological ecosystems of the lagoon area near the pass, but also on the environment and socio-economy, creating a new area (Guézo et *al.,*2022). This method could therefore be improved through the determination of the maximum salt tolerance concentration of water hyacinth for a better alternative in the fight against the proliferation of hyacinth without interfering on the ecosystem of the lagoon area. This study, thus based on the use of six different salt concentration through the use of seawater, allows to evaluate the performance of different growth parameters such as the length of the leaves, the roots length, the Stem length, number of leaves, stem diameter, and number of dead leaves were counted and measured at the beginning and following each week throughout the study. Numerous studies have shown that sodium chloride is likely to affect the growth, and therefore the survival, of invasive aquatic plants (Guézo, 2022; Egnankou et *al.*, 2016). The results of the preliminary experiment carried out to determine the maximum salt tolerance concentration of water hyacinth showed that plant mortality begins from saline concentrations of 0.248 moL.L^{-1} , 0.372 mol.L^{-1} and 0 .62 mol.L^{-1} . Based on this result, we can say that the saline medium with a saline concentration of 0.248 mol.L $^{-1}$ is toxic for water hyacinth. The decrease in the length of the leaves following growing of the plant in a medium concentrated in salt of 0.062 mol.L $^{-1}$ and 0.124 mol.L $^{-1}$, from the first week with respective average values of 3.21 ± 0 ; 1.68±0.719 and 3.47±0.49; 1.30±0.547 could of course be linked to the presence of salt in the culture medium. According toBelfakih et *al.,*(2013), effect of salt results in a significant reduction in plants' leaf length (Belfakih et *al.,* 2013). Other authors have also reported that the impact of salt on leaf expansion is more obvious with a significant reduction in leaf area (Laaziza et al., 2007); trait which includes two different parameters of the leaf namely the length and the width. In case of the roots length (RL), the evolution observed from the first week until the second week is explained by the tolerance of the plants in salt with the concentrations of 0.062 mol.L^{-1} and 0.124 mol.L^{-1} before reaching the fourth respective values of 9.14±4.001; 13.14±1.09 and 12.21±5.23 13.49±4.910 for both media (M2 and M3). This increasing at the fourth week could be explained by the addition of poultry manure at the third week to all media as reported by several authors (Ngoyi et *al.,* 2020; Muladji, 2011; Ognalaga et *al.*, 2016) which justify that poultry manure improves the conditions for plant development. Also, the growth of a culture depends according to Mukendi et *al.,*(2017) on the availability of nutrients through the manures provided. The number of leaves increased slightly one week after application until the second week and started to regress after the third until the end of the experiment for M2; and a decrease from the first week until the end for M3. These observations corroborate with the results obtained by Laaziza et *al.*, 2007 which indicate that salinity causes a consequent reduction in the number of leaves in plants. Similar variations were observed on

the stem diameter for M2 and M3. According to Guezo (2022), the effect of salinity generally results in a reduction in stem growth. There is not a large significant difference between M2, M3 media for the NL and SD variables. However, it was found that the saline medium had a much greater influence on the growth of the diameter of the stem at 0.124 mol.L^{-1}. The decrease in stem length in the third week could be related to the assessed salt concentrations, as highlighted by Karoune et *al.,* (2017). For this author, the effect of salinity results in a reduction in stem growth which is a function of cell division and elongation. For petiole length, the results obtained show that there was a regression after the evaluation until the end of the experiment. Similar to our results, Belfakih et *al.*, (2013), report that the inhibitory action of NaCl on the development of the aerial parts is manifested by the reduction in petiole length (Belfakih et *al.*, 2013).

In the absence of salt, the plants present a better development of the aerial parts and also of the roots. Thus, during the evaluation with simple tap water, the different traits presented increasing average values throughout the experiment (M1) and justifies that the natural conditions for the development of the hyacinth are more or less met.

CONCLUSION

The saline environment limits the growth of water hyacinth which is a plant causing harmful problems on the socio-economic life of the population while making it difficult to access their homes, preventing fishing activities. Water hyacinth also poses a threat to the aquatic environment by suffocating fish and other animals living in the water; with the consequent deterioration of the population' health. It should also be noted that the excess of salt in the medium hinders the proper functioning of the environmental ecosystem. It makes the environment unviable for freshwater living beings. It emerges at the end of this study that the maximum salt concentration tolerated by water hyacinth is 0.062 mol.L^{-1}. This dose considerably slowed down the development of the plant justified by decreasing in the different growth parameters measured. Beyond this concentration, *Eicchornia crassipes* can no longer tolerate salinity, thus leading to the death of plants in culture at different concentrations of 0.248 mol.L^{-1}; 0.372 mol.L^{-1},and 0.62 mol.L^{-1}. Application of this method to fight against the proliferation of this plant requires, in fact, more research on the level of acceptability of other species present in the ecosystem of the development of water hyacinth.

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