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Agronomic performances of plantain (*Musa paradisiaca,* AAB, Corne 1) vivo-plants produced on a substrate treated with NaCl solutions and *Sargassum natans* extracts

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ABSTRACT: In Côte d'Ivoire, plantain is a widely consumed food. It's grown in all humid agroecological areas of the country. Despite its adaptation to these areas, plantain production remains insufficient on the coast of cultivation soils salinization. This study aimed to improve plantain production in coastal area of Côte d'Ivoire by obtaining vivo-plants. It was conducted to evaluate agronomic performance of plantain vivo-plants from environments treated with increasing solutions of NaCl (0, 5, 10 and 15 g/l) and *Sargassum natans* (25, 50 and 100%). Two-month-old plants were transferred to plots developed in Azaguié locality and some production and yield parameters were evaluated. Results showed that time interval between planting and flowering and production cycle were short in plants from environments treated with *S.natans* (50 and 100%) and NaCl (5 and 10g/L) solutions. Average mass of bunches and middle finger varied according to plants from different treatments. However, the best yields were obtained with T 50% concentration of *S. natans* extract (18.33 t/ha) and 5g/L of NaCl solution (16.32 t/ha) compared to control (14.35 t/ha). In conclusion, concentrations of 5 g/L of NaCl solution and T 50% of *S. natans* extract can be used to evaluate tolerance of plantains to soil salinity to improve yield.

KEYWORDS: *Musa paradisiaca,* NaCl, *Sargassum natans,* agronomic parameters.

1 INTRODUCTION

Plantain (*Musa paradisiaca* L.) is a monocotyledonous plant belonging to Musaceae family. It is cultivated in many regions of world, mainly in Latin America and Africa where it's a staple food for populations [1]. In sub-saharan Africa, it ensures food security and contributes to fight against poverty by improving producers' income [2]. In Côte d'Ivoire, it's the third most important food crop after yam and cassava [3]. Annual production of plantain, estimated at more than 1.7 million tonnes, remains insufficient to meet food needs of a rapidly growing population [4]. Like all plants, plantain cultivation in Côte d'Ivoire is faced with several environmental factors limiting its production, including disease and pest attacks as well as soil salinization in coastal area [5]. To overcome difficulty of producing plants in salinity environment, several scientific approaches are being considered, such as selection of tolerant varieties, genetic mutation and stimulation of natural defense plant using biotic and abiotic elicitors. Previous work carried out by some researchers on rice [6] and banana [7] has shown that NaCl could be used as a marker of plant resistance to soil salinity. [8] also showed that liquid extract from *Sargassum natans* would increase tolerance of plants to salinity stress. Objective of this study is to evaluate agronomic performances of plantain vivo-plants from media treated with NaCl and *S. natans*.

2 MATERIAL AND METHODS

2.1 MATERIAL

2.1.1 PLANT MATERIAL

Plant material consists of two-month-old plantain (*Musa paradisica* AAB Corne 1) vivo- plants (**Fig. 1**) from stem fragment plant multiplication technique. This cultivar represents more than 80% of national plantain production in Côte d'Ivoire and is grown in almost all humid pedoclimatic zones of country [9].

Fig. 1. plantain vivo-plants used

2.1.2 PRESENTATION OF STUDY AREA

Study was conducted in Azaguié (5°18' North latitude and 4°09' West longitude) located 20 km from Abidjan city, Côte d'Ivoire (**Fig.2**). This area is characterized by a hot and humid environment with four seasons including two rainy seasons and two dry seasons. Longest rainy season lasts five months. Average annual rainfall is 1200 mm with a temperature varying between 23 and 28°C [10].

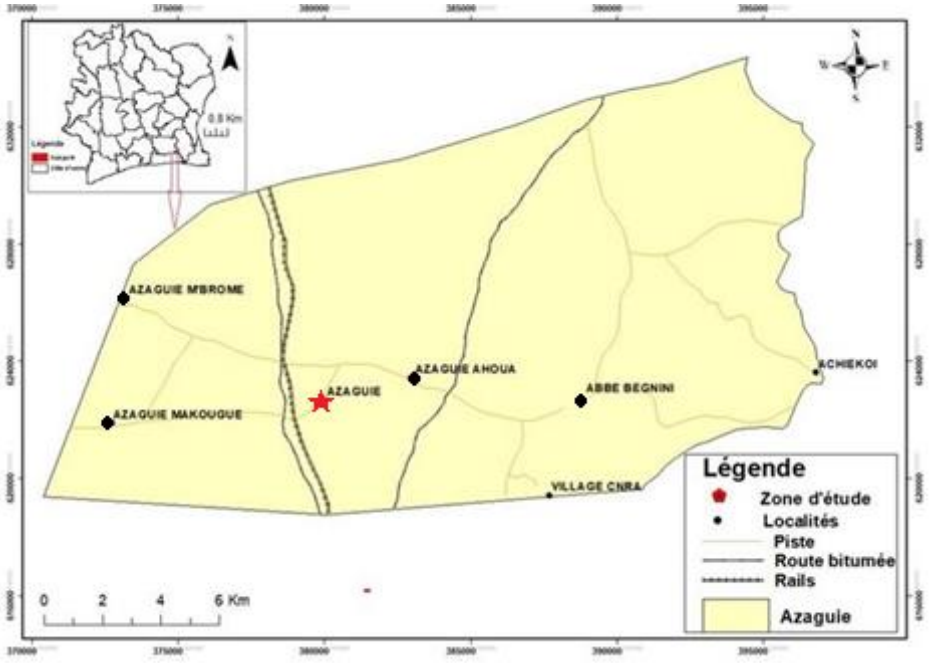

Fig. 2. Map of study site in Azaguié

2.2 METHODS

2.2.1 PREPARATION OF ELICITOR SOLUTIONS

Sodium chloride (NaCl) solutions were prepared according to [11] method. A mass of 5, 10, 15, 20 and 30 g/L of NaCl was dissolved respectively in 1 L of tap water. As for *Sargassum natans* solution, modified method of [12] was used. Harvested algae were rinsed thoroughly with tap water to remove sand and sea salt. They were then sorted to remove impurities. Clean algae were dried for 72 hours at 37 ºC in an oven and then crushed using a GRT-By600 electric grinder. To make algae extract, 200 g of algae powder were soaked in 2 L of tap water. This mixture was placed in a water bath at 40 °C for 30 minutes. After cooling, solution was filtered using a 5 µm mesh

sieve. This algae extract obtained constituted mother solution (100 %) from which concentrations of 25 and 50% were obtained. Different solutions were stored in Erlenmeyer flasks at 37°C before use.

2.2.2 PLANT PRODUCTION

Vivo-plants from stem fragment plant multiplication technique was used to produce plants. Explants prepared and dried using this technique were inoculated into pots containing disinfected sawdust. Pots were watered with different solutions of NaCl (0, 5, 10 and 15 g/L) and *Sargassum natans* (25, 50 and 100%), at a rate of 500 mL of solutions (NaCl or *S. natans*) every three days. After four weeks of cultivation, leafy rejects were collected and transplanted into 12 cm x 16 cm polyethylene bags, filled with a mixture of potting soil and sand treated with fungicide. Bags were placed under a shade in batches of 50 plants in a completely random arrangement. After two months, vigorous plants were selected and transferred to field.

2.2.3 EXPERIMENTAL DESIGN AND MAINTENANCE OF PLANTS IN FIELD

Study was carried out in an experimental field of 500 m^2 previously left fallow. Plants were planted according to a completely randomized Fisher block design with three repetitions. Vivo-plants from environments treated with NaCl solutions (0; 5; 10; 15g/l) and *Sargassum natans* extracts (25, 50 and 100%) were used. Thirty (30) individuals per type of plant were planted with a spacing of 2.5 m between plants and 2.5 m between rows giving a classic density of 1500 plants/ha. Manual weeding with a machete and removal of dry leaves were regularly carried out. At flowering and harvest, agromorphological characterization of banana plants was carried out using observation using descriptor proposed by [13] (**Table 1**).

Table 1. Estimate method of plantain parameters at flowering and harvest

Parameters	Assessment method
Planting- flowering Interval time (j)	Planting-flowering interval time is the number of days elapsed between planting of vivo-plants and beginning of inflorescence. Average planting-flowering interval time (PFT) was calculated according to following formula: $PFT = \sum(\text{Planting-flowering duration})/NP$ NP: total number of plants
Plant height (cm)	Plant height was measured from pseudo stem base to plant top at level of the "V" formed by the last two functional leaves using a tape measure. Average height of plant (HiP) was calculated using following formula: $HiP = \sum(hi)/NP$ HiP = Average height of plant, hi = height of a plant; NP = total number of plants
Circumference of pseudo-stem (cm)	Pseudo stem circumference was measured from 10 cm from ground level. Average pseudo stem circumference (C) was calculated using the following formula: $C = \sum(Cp)/NP$ C = average circumference of pseudo stem; Ci = circumference of each plant at flowering; NP = total number of plants
Number of green leaves at flowering	Number of green leaves was counted at time of inflorescence emergence. Average number of green leaves (GL) at inflorescence was calculated using following formula: $GL = \sum(gl)/NP$ GL = Average number of green leaves at flowering; gl = number of green leaves of each plant at flowering; NP = total number of plants
Number of rejects at flowering	Number of rejects emitted by each plant was counted at flowering. Average number of rejects (NR) was calculated as follows: $NR = \sum(nri)/NPi$ NR = average number of rejects; nri = number of rejects per main plant at flowering; NPi = total number of main plants
Height of successor reject at harvest (cm)	Height of successor reject is measured at harvest using a tape measure. Average height of successor reject (HSR) was estimated using following formula: $HRS = \sum(hsr)/NS$ HRS = average successor reject height; hsr = height of a successor reject; NS = total number of successors rejects
Planting-harvest interval time (j)	Planting-harvest interval time is the number of days between planting and appearance of a physiologically mature finger on bunches. Mean planting-harvest interval time (PHT) was calculated using following formula:

	PHT = ∑(Planting-harvest duration)/NP NP: total number of plants
Mass of bunches (kg)	Mass of bunches is obtained using a kitchen balance and average mass (MH) is calculated according to following formula: MH = ∑ (m)/N MH = average mass; M = mass of each bunch; N = total number of bunches
Number of bunches hands	Number of bunches hands is manually evaluated. Average number of hands (NH) is calculated using following formula: NH = ∑(nh)/N NH = average number of hands, nh: number of hands per bunches, N: total number of bunches
Number of fingers	Number of fingers carried by bunches is manually evaluated. Average number of fingers per bunches (NF) is evaluated according to following formula: NF = ∑(nf)/N NF=average number of fingers, nf: number of fingers per diet, N: total number of bunches
Middle finger mass (g)	Mass of median finger of second hand was obtained by weighing using a precision balance. Average mass of median finger (MM) was calculated according to formula below. MM = ∑(mass of a median finger)/N MM: average mass of median fingers; N: total number of bunches
Middle finger length (cm)	Length of middle finger located on second hand of bunches was measured using a graduated ruler. Average finger length (FL) was calculated according to formula below: FL= ∑(L)/N FL= average median finger length, L: length of each median finger, N: total number of bunches
Estimated yield (t/ha)	At harvest, yield was determined by sum of masses of banana bunches number collected on plot area, expressed in kg/m^2, then converted into t/ha. Average yield (Y) was calculated using formula opposite: Y = Σ (bunches mass) / N Y: average yield. N: total number of banana bunches harvested on plot

2.3 STATISTICAL ANALYSIS

All data were subjected to a one-way or two-way analysis of variance (ANOVA) using Statistica software, version 7 at 5 % threshold. When $p < 0.05$, difference is considered significant and a post-ANOVA test, Newman-Keuls test is performed to identify homogeneous groups.

3 RESULTS

3.1 EFFECT OF NACL SOLUTIONS AND SARGASSUM NATANS EXTRACTS ON PLANT HEIGHT, PSEUDO STEM CIRCUMFERENCE, INFLORESCENCE EMISSION TIME AND NUMBER OF GREEN LEAVES AT FLOWERING

Table 2 presents values of plant height, pseudo stem circumference, number of green leaves at flowering and planting-flowering interval time. At flowering, all these parameters indicated varied according to treatments except planting-flowering interval time ($p = 0.24$). Average height of pseudo stems from *Sargassum natans* environment was greater (321.66 cm), followed by NaCl treatments (283.33 cm) and control (292.33 cm). Concerning circumference of pseudo stems, plants from sargassum-treated environments recorded largest values (63.66 cm) while T10g/L and T15g/L treatments recorded smallest circumferences (56.00 cm). Similarly, number of green leaves brought to flowering was much greater for high concentrations of *S. natans* extract (11 leaves) and NaCl T5g/L solution (10.3 leaves).

Table 2. Agromorphological parameters at flowering of plantain plants

Elicitor	Treatments	Growth parameters			
		Planting- Flowering Interval (J)	Average plant height (cm)	Average circumference of pseudo-stem (cm)	Number of green leaves at flowering
Control	water	270.00±5.00^{a}	292.33±1.52^{c}	63.33±1.52^{a}	9.66±0.57^{ab}
NaCl	T5g/l	280.33±5.50^{a}	283.33±2.88^{a}	61.00±1.73^{ab}	10.3±0.57^{ab}
	T10g/l	281.00±12.1^{a}	280.00±1.00^{a}	58.33±1.52^{b}	8.66±0.57^{a}
	T15g/l	278.00±18.2^{a}	280.33±0.57^{a}	56.00±1.00^{c}	9.00±0.00^{a}
Sargassum natans	T25%	268.33±6.65^{a}	302.33±2.51^{b}	62.33±2.08^{a}	9.66±0.57^{ab}
	T50%	265.66±3.78^{a}	323.33±5.03^{b}	63.00±1.00^{a}	11.0±1.00^{b}
	T100%	267.66±2.51^{a}	321.66±3.78^{b}	63.66±2.08^{a}	11.0±1.00^{b}
	p	0.25	0.001	0.001	0.004

In same column, numbers followed by same alphabetical letter are statistically identical at 5% threshold according to Newman-Keuls test.

3.2 Effect Of NaCl Solutions And Sargassum Natans Extracts On Number Of Rejects Emitted, Height Of Successors Rejects And Harvest Time

Table 3 presents data on number of days elapsed between planting-harvest, average number of successors rejects per plant and average height of main successor reject. Time between planting and harvest date is not influenced by origin of vivo-plants (p = 0.39). This time varied from 343 days to approximately 360 days. As for number of successors rejects, it was high in plants from environments treated with *Sargassum natans* extracts. Values varied from 9 to 10.3 leaves. Average height of main successor was high in plants from both NaCl and sargassum media. However, highest value was recorded in plants from sargassum T100% media (111 cm).

Table 3. Evaluation of harvest time, number of successor rejects emitted and height of main successor reject

Elicitor	Treatment	Growth parameters		
		Planting-harvest interval (j)	Average number of successors rejects per plant	Average height of main successor rejects (cm)
Control	water	349.33±4.04^{a}	6.33±0.57^{a}	93.33±6.50^{ab}
NaCl	T5g/l	350.00±5.00^{a}	5.33±0.57^{a}	92.00±10.5^{ab}
	T10g/l	357.00±24.0^{a}	5.66±1.52^{a}	88.66±8.08^{a}
	T15g/l	360.66±25.3^{a}	6.33±0.57^{a}	87.00±8.18^{a}
Sargassum natans	T25%	343.00±9.84^{a}	9.00±1.00^{b}	91.33±4.72^{ab}
	T50%	346.66±2.88^{a}	9.33±1.15^{b}	93.33±7.63^{ab}
	T100%	347.66±2.51^{a}	10.3±0.57^{b}	111.6±10.4^{b}
	p	0.39	0.001	0.04

In same column, numbers followed by same alphabetical letter are statistically identical at the 5% threshold according to Newman-Keuls test.

3.3 Effect Of NaCl Solutions And Sargassum Natans Extracts On Number Of Hands, Fingers And Average Length Of Median Finger

Average number of hands, fingers and average length of median finger on a bunch are recorded in Table 4. Average number of hands per bunches was statistically different depending on origin of vivo-plants (p = 0.04). This number varied from 6 to 7 in plants from NaCl-treated environments and from 7 to 9 in plants from Sargassum-treated environments. Average number of fingers per bunches was also influenced by treatments (p = 0.001). Greatest number of fingers (51 fingers) was observed in plants from environments treated with *Sargassum natans* extract (T100%) compared to 29 fingers for T15%. Statistical analysis revealed a highly significant difference for finger length parameter (p = 0.001). Average length of middle finger is greater in plants from Sargassum-treated environments (19 cm).

Table 4. Evaluation of number of hands and fingers per banana bunches

Elicitor	Treatment	Performance parameters		
		Number of hands per bunches	Number of fingers per bunches	Middle finger length (cm)
Control	water	7.33±0.75^{ab}	36.00±1.00^{a}	15.00±1.00^{a}
NaCl	T5g/l	7.00±3.75^{ab}	35.66±3.21^{a}	16.00±1.00^{a}
	T10g/l	6.33±0.75^{ab}	32.66±3.21^{a}	17.00±0.00^{a}
	T15g/l	6.00±3.75^{a}	29.00±2.64^{a}	16.66±0.57^{ab}
Sargassum natans	T25%	8.00±6.75^{ab}	45.00±2.64^{b}	16.66±1.15^{ab}
	T50%	7.66±0.75^{ab}	46.33±3.51^{b}	19.00±1.00^{bc}
	T100%	8.66±6.75^{b}	51.00±3.60^{b}	19.33±1.52^{c}
	P	0,04	0,001	0.001

In same column, numbers followed by same alphabetical letter are statistically identical at the 5% threshold according to Newman-keuls test.

3.4 Effect Of NaCl Solutions And Sargassum Natans Extracts On Bunches And Middle Finger Mass, And Yield

Table 5 presents data on mean bunches mass, mean middle finger mass and yield. Banana plants from environments treated with *Sargassum natans* extracts produced higher bunches mass. Bunches mass varied from 13.33 (Control) to 15.66 kg in plants from Sargassum treatments. Low bunches masses were recorded in plants from environments treated with NaCl solutions. Mean middle finger mass was higher in bunches of plants from environments treated with *S. natans* T50 (172g) and T100% (186 g). Regarding average yield per hectare, it was higher in plants from environments treated with *S. natans* compared to control. Average yield varied from 14.66 to 16.33 t/ha in plants from environments treated with *S. natans* extracts. Similarly, it varied from 13.66 to 16.66 t/ha in plants from environments treated with NaCl solutions.

Table 5. Evaluation of bunches mass, middle finger and yield

Elicitor	Treatment	Performance parameters		
		Average mass of bunches (kg)	Average mass of middle finger (g)	Estimate of Performance (t/ha)
Control	water	13.33±1.52^{ab}	162.66±2.51^{c}	14.33±0.57^{a}
NaCl	T5g/l	14.00±1.00^{a}	161.33±2.51^{a}	16.33±0.57^{b}
	T10g/l	13.33±0.57^{ab}	160.33±2.51^{a}	14.66±0.57^{a}
	T15g/l	11.66±1.52^{b}	157.66±3.05^{d}	13.66±0.57^{a}
Sargassum natans	T25%	14.33±0.57^{a}	172.33±2,51^{e}	16.66±0.57^{bc}
	T50%	15.66±1.15^{a}	183.00±2.64^{b}	18.33±0.57^{d}
	T100%	15.33±0.57^{a}	186.66±1.52^{b}	17.66±0.57^{cd}
	P	0.005	0.001	0.001

In same column, numbers followed by same alphabetical letter are statistically identical at 5% threshold according to Newman-Keuls test

4 Discussion

Plantain plays an important role in global food security and is a source of income for producers [5]. Several techniques have been developed to improve seed production of this plant as well as its yield. Our study is part of this approach by producing vivo-plants on media treated with sodium chloride (NaCl) solutions and liquid extract of *Sargassum natans* (ELS). Effects of stimulating banana vivo-plants with NaCl and ELS were evaluated in terms of plant growth and yield. Indeed, according to several authors, seaweed extracts are known for their ability to stimulate growth of cultivated plants since they contain growth regulators such as auxins, gibberellins, cytokinins, betaines and major nutrients [7], [8]. They are also considered effective biofertilizers in agriculture [9], [10]. Maximum height of plants treated with *S. natans* extracts was on average 312 cm compared to 280 cm for plants treated with NaCl solutions and 292 cm for control. Concerning circumference, it varied between 56 and 63 cm. These results are significantly higher than those obtained by [11]

on same banana cultivar and [12] on two false horn banana cultivars. However, our results are in agreement with previous work by [13] on effect of liquid extract of green algae (*Chaetomorpha linum*) on stimulation of germination and growth of durum wheat (*Triticum turgidum*) and [14] on tomato (*Lycopersicon esculentum*). It is shown that the growth and production of durum wheat (*T. durum*) were stimulated following use of liquid extract of brown algae *S. vulgare* [15]. High number of green leaves at flowering was similar to that observed in Big Ebanga banana cultivar studied by [16]. Increase in height and circumference of pseudo-stems of vivo-plants according to increasing NaCl concentrations would be an adaptive sign developed in banana to salt, as opposed to depressive effect observed in other sensitive glycophytes [17**].** According to [18], high number of functional leaves at flowering is an essential characteristic to ensure good development of bunches and quality fruits. Best results were obtained with low concentrations of NaCl solutions (5g/L) and *S. natans* extracts (T50%). This is consistent with results of [8] obtained following application of lowest concentration (20 %) of liquid algal extract (*Codium decorticatum*) in pepper (*Capsium annum*) significantly increasing fresh mass, dry mass, and number of pods. Pretreatment of vivo-plants would thus have stimulated cellular metabolism allowing better fruit filling, heavier bunches and high yield.

However, reduction in number of leaves as flowering approaches observed in plants from environments treated with higher concentrations of NaCl solutions (10 and 15 g/L), could be explained by mobilization of photosynthesis products for growth and development of fruits to detriment of vegetative growth [19]. Average mass of bunches was 17 kg for plants treated with *S. natans* extracts with an average of 54 fruits per bunches, compared to 34 for control. Overall, there was a clear improvement in production characteristics of bunches of this variety by application of NaCl solutions and *S. natans* extracts. Indeed, several research studies have shown that algae contain different molecules such as polysaccharides, proteins, polyunsaturated fatty acids, pigments, polyphenols and minerals [20], [21]. Among these compounds, some are used as elicitors to stimulate natural defense of plants [8]. These seaweed extracts would facilitate retention of water in soil and absorption of trace elements (Cu, Zn, Mn, Fe, Co, N) necessary for plants [22]. In addition, [23] showed that seaweed extracts improved tolerance of plants to abiotic stresses such as drought and soil salinity. Our results confirmed excellent agronomic performances of banana cultivation obtained from vivo-plants from environments treated with *S. natans* extracts.

5 CONCLUSION

Adaptation to stress salinity is essential for crops in general and specifically cultivation of plantain intended to be cultivated in coastal area of Côte d'Ivoire. In light of results obtained, concentrations of NaCl (5g/l) and *Sargassum natans* (50 and 100%) improved growth and yield of plantain. These results support biostimulant potential of aqueous extract of *S. natans* which can be used for production of vivo-plants of plantains tolerant to salinity. These plants from a young age would have accumulated metabolites that promote their adaptation to stress salinity. In field, treatments promoted precocity of flowering and fruiting periods in plants from environments treated with NaCl and *S. natans* compared to controls. However, best yields were recorded by the application of *S. natans* extracts.

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