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Research Article

Plant growth, Yield and Leaf Nutritional value of Jute (*Corchorus olitorius* L.) as Influenced by Banana Peel levels under Salt Stress conditions in Coastal region of Cameroon

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Abstract

In the world, millions of hectares of cultivated land are affected by salt, making salinity a major constraint for plant production.

The effects of different levels of banana peel on growth, yield, and chemical changes of jute (*Corchorus olitorius* L.) under salt stress were examined herein. Response of jute to applications of different levels of banana peel (5, 10, and 15 t ha^{-1}), as well as water irrigation salinity at 50, 100, and 200 mM NaCl were evaluated under greenhouse conditions.

The outcome uncovered that salinity caused significant reduction of plant growth and yield parameters, chlorophyll (at 21.6%), LRWC (at 18.9%), P (at 57.1%) and K (at 45.4%) content, while MDA content (at 351.8%), Na (at 266%), soluble proteins (70.2%), total phenolic (at 23.4%) accumulation showed an increase from 0 to 200 mM NaCl without BP application. The banana peel treatments (at 15 t ha^{-1} under 200 mM NaCl) diminished significantly damaging effects caused by salinity via a reduction in the Na (at 28.4%), total soluble sugars (at 17.8%), total flavonoids (at 20.1%), which enhanced number of leaves per plant (37.1%), plant height (at 19.8%), leave yield (at 41.4%), LRWC (at 12.8%), Mg (at 24.2%) and reduced the MDA content (at 20%), presenting a favorable effect in reducing the oxidative stress that emerged from salt stress.

It could be concluded, that the application of 15 t ha^{-1} of BP was superior in promoting plant growth, yield, and nutritional quality than others under control and in the saline soils in this study. BP at 15 t ha^{-1} had a more reduced damage of salt stress effect on growth, yield, nutritional value, and use efficiency.

More Information

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Keywords: Antioxidant; Banana peel; Osmolytes; Jute; Salinity

Abbreviations: ASA: Ascorbic Acid; BP: Banana Peel; Ca: Calcium; CHL: Chlorophyll; DAP: Days After Planting; DAS: Days After Sowing; LDW: Leaf Dry Weight; LFW: Leaf Fresh Weight; LRWC: Leaf Relative Water Content; LY: Leave Yield; MDA: Malondialdehyde; Mg: Magnesium; N: Nitrogen; NL: Nnumber of Leaf; C: Organic Carbon; P: Phosphorus; PH: Plant height; K: Potassium; Na: sodium; SP: Soluble Protein; SD: Stem Diameter; S: Sulfur; TFC: Total Flavonoids Content; TLA: Total Leaf Area; TP: Total Phenol; TSS: Total Soluble Sugar; WAS: Week After Sowing; Zn: Zinc

Introduction

Jute (*Corchorus olitorius* L.) is an annual flowering plant in the Tiliaceae family and the most significant source of natural fiber, covering about 80% of global bast fiber production [1]. Its leaves are in abundance of iron, folate, protein, fiber, calcium, riboflavin, carotene, vitamin C, and phenols, and have high zinc bioavailability and appreciable amounts of other proximate components. And minerals [2]. Cooked leaves and tender shoots that are eaten along with food staples are recommended for pregnant and nursing mothers because of their high iron content [3]. Health-flourishing effects of plant-derived secondary metabolites in human health, including antioxidative, anticarcinogenic, antibiotic, and pharmacological effects, are well documented [4]. Leaves of *C. olitorius* possess an abundance of antioxidant compounds associated with various biological properties, which include diuretic, analgesic, antipyretic, and antimicrobial activities, antitumor [5] and phenolic antioxidative compounds [6], hypoglycemic [7], antiobesity [8] and gastroprotective [9].

However, salinity is a significant abiotic stress factor that threatens agriculture in both arid and semiarid environments. It affects over 20% of irrigated land worldwide, and 40% of the food produced around the world is impacted by increased amounts of salt, as the amount of land affected by salinity is on the rise. It is also estimated that 50% of the cultivable land will be affected due to salinity by 2050 [10]. Salt stress induces changes in the biochemical, physiological, and morphological responses of a plant, which leads to reduced growth, yield, biomass, and quality of crop plants. Salinity's significant inhibitory impact on plant growth and yield was due to: (1) osmotic influence, (2) ion toxicity, and (3) nutritional deficiency leading to decreased photosynthetic efficacy and other physiological disorders [11]. Salinity causes excessive reactive oxygen species (ROS) accumulation, possibly resulting in enzyme inactivation, damage to DNA, lipid peroxidation, protein oxidation, and interaction with other essential plant cell components. Two solutions can be chosen for sustainable agriculture in salt soils: planting salt crops or using salt-soil recovery methods.

Various organic improvements such as garden compost, green manure, farmyard manure, and urban solid waste compost have been applied to soil to increase soil quality and crop yields [12]. As chemical fertilizers are both expensive and have dangerous effects, the use of organic compound solutions is on the rise. Organic fertilizers result in improved soil composition and increased availability of nutrients, which support quality and yield protection, and they are less expensive than synthetic ones [13]. Adding organic waste to the soil, which reduces evaporation, while moderating the temperature of the soil, reduces stress on the roots of the plant and supplies nutrients, which in turn, results in productivity enhancement [14]. Moreover [15], reported that organic foods are significantly more nutritious than conventional foods and these had fewer pesticide residues and antibiotic-resistant bacteria. Organic manure has been reported to improve fruit and vegetable bioactive compound contents, such as beta-carotene, flavonoids, lycopene, and phenol, as well as antioxidant activity [16]. [17] suggested that organic manures could be the safest way to preserve soil fertility, sustainability, and salt resistance. Various ecological improvements including farmyard manure, compost, Banana Peel (BP), and Poultry Manure (PM) can be used to reinforce saline soils. Banana peels contain the three macronutrients: Nitrogen, Phosphorus, and Potassium, as well as many micronutrients, which promote the growth of garden plants from seed germination to blooms and fruits. Because of these nutrients, banana peels also help plants to resist diseases [18]. Organic improvements enhance soil physical, mechanical, and biological properties under saline conditions.

The objective of this study is to determine the optimum level of banana peel application for maximum growth, yield, chemical compositions, and quality of jute (*Corchorus olitorius* L.) left under salt stress. Yield, chemical, quality, and growth indicators were measured to determine the effects of the banana peel on jute in comparison with the control to determine if successful cultivation of this wild vegetable requires the use of fertilizers and the quantities that produce favorable results under the salt stress conditions in the littoral region of Cameroon.

Materials and methods

Experimental site

The experimentation took place in 2021 at the University of Douala research farm (4°01N, 9°44 E, 13 m.a.s.l.), in the coastal region of Cameroon. The climate belongs to the equatorial domain of a particular type called Cameroonian characteristics by two seasons with a lengthy rainy season (at least 9 months), abundant rainfalls (about 3597 mm per year), and high and stable temperatures (26.7 °C). The relative humidity remains high the whole year and near 100%. The soil of the experimental site is classified as yellow ferralitic soil.

Plant growth conditions and treatment

Jute potager (*Corchorus olitorius* L.) has been used as plant material. *Seeds were provided by the breeding program of the TECHNISEM (SEMAGRI, Douala).* The seeds were surface sterilized with 3% sodium hypochlorite for 20 min and washed four times with deionized water. The seeds were planted in cavity trays in the greenhouse of the Faculty of Science at the University of Douala, Cameroon, on 11th April 2021 and transplanted when seedlings reached 8 cm in height into the prepared polythene bags containing 5 kg of sterilized soil. Each pot of seven liters capacity is perforated at the bottom to allow unimpeded drainage. The pots were arranged in a complete randomized design with one plant per pot and four replicates per treatment. The plants were watered immediately after transplanting to avoid drought stress. All plants were fertilized daily with a modified nutrient solution (in g L^{-1}): 150 g $Ca(NO_3)_2$, 70 g KNO_3, 15 g Fe-EDTA, 0.14 g KH_2PO_4, 1.60 g K_2SO_4, 11 g $MgSO_4$, 2.5 g $CaSO_4$, 1.18 g $MnSO_4$, 0.16 g $ZnSO_4$, 3.10 g H_3BO_4, 0.17 g $CuSO_4$ and 0.08 g MoO_3 [19]. The pH of the nutrient solution was adjusted to 7.0 by adding HNO_3 0.1 mM. For the determination of agro morphological, physiological, and biochemical responses to salt stress, the jute potager was subjected to 0 (control), 50, 100, and 200 mM NaCl. Plants were watered with deionized water every morning. *The amendment in each case was applied 5 WAS with four fertilization rates (0, 5, 10, and 15 t h^{-1}) each of Banana peel and 300 kg h^{-1} of NPK (15 – 15 – 15).* The banana peel was collected in the study area from a banana farmer, dried, and ground*. Selected banana peel chemical properties are shown in* Table 1*.* Phytosanitary treatment has been realized with Emamectine benzoate (insecticide) used before the transplantation of plants and Thiophanate-methyl (fungicide).

Table 1: Nutrient contents of banana peel dry and ground (BP).

	Nutrient concentration (%)							
Nutrient source	N	Iron	P	Na	K	Ca	Mg	C/N
BP	2.04	0.62	0.28	0.027	1.91	0.58	1.44	24.83

Soil moisture content determination, banana peel sampling and analysis

Soil samples were collected from representative spots on the experimental site from where soil was collected for potting using soil auger to a depth of 20 cm, the samples were made into a sample. A sub-sample was taken, air-dried, crushed, and sieved with a 2-mm mesh sieve after which physical and chemical analyses were carried out (Table 2). The following chemical analyses were done on the soil, tap water, and banana peel (Tables 1-3). Organic carbon (C), was determined by the wet oxidation procedure [20] and Total Nitrogen (N) by the micro-Kjeldahl digestion method. Magnesium (Mg) was extracted using the Mehlich 3 method and determined by auto ANALYSER 5Technicon 2). The total and available soil phosphorus (P) were determined by the method of [21]. The soil was measured potentiometrically in a 1:2.5 soil: water mixture. Calcium (Ca), potassium (K), and sodium (Na) were determined by an aflame photometer (JENWAY) as described by [22]. Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, SO_4^{2-}, NO_3^{-}, and Cl^{-} content in the water tap was determined by using the colorimetric amperometric titration method [23] (Table 3). Electric conductivity and pH were determined by conductometer.

Plant measurements

Seedlings were harvested 14 WAS by carefully removing and washing the soil particles from the roots, after which the plant parts were separated into shoots and roots [24]. The tissues (leaves) were dried for 24 h at 105 ˚C [22]. The dry samples were weighted. Plant samples were harvested after 4 months of culture and under 10 weeks of water stress, the plant was collected to determine agro morphological characters (number of leave per plant, stem diameter, total leaf area, fresh leave weight, dry leave weight, plant height, leave yield) in jute (*Corchorus olitorius* L.).

Table 2: Physical and chemical characteristics of soil used.

Physio-chemical properties	Quantity
Clay %	14.21 ± 1.98
Coarse sand%	27.93 ± 2.76
Fine sand%	25.72 ± 2.58
Coarse silt %	26.02 ± 2.71
Fine silt %	6.31 ± 0.53
Total carbon %	0.77 ± 0.09
Total nitrogen %	0.33 ± 0.06
Ratio C/N %	2.33 ± 0.08
Moisture (%)	1.01 ± 0,12
Phosphorus (ppm)	4,82 ± 0.17
Potassium (g kg^{-1})	0.26 ± 0.08
Sodium (g kg^{-1})	2.8 ± 0.19
Calcium (g kg^{-1})	0.33 ± 0.08
Magnésium (g kg^{-1})	0.17 ± 0.07
pH	8.47 ± 0.62
EC dS/m	2.24 dS^{-1}

Table 3: Chemical characteristics of irrigation water.

Chemical characteristics									
Irrigation Water	Ca^{2+} (mg g^{-1})	Mg^{2+} (mg g^{-1})	K^{+} (mg g^{-1})	HCO_3^{-} (mg g^{-1})	Na^{+} (mg g^{-1})	SO_4^{2-} (mg g^{-1})	Cl^{-} (mg g^{-1})	Ph	CE (dS m^{-1})
Tap water	233.2	116.8	23.4	61.7	438.1	518.8	26.1	7.31	1.34

The relative water content (RWC) in the leaf was recorded according to the formula as follows: RWC = (FFW - FDW)/(TW - FDW) × 100, where FFW is fresh weight, FDW is dry weight, TW is turgid weight and TLA (length × width × 0.80 × total number of leaves × 0.662) were calculated using the methodology described by [25]. Fresh leaves were extracted with acetone (80%) (Sigma-Aldrich Co. LLC) and placed for one hour at 5 ºC. The extractions were centrifuged for 15 min at 3,000 x *g*. Chlorophyll *a* and *b* content were measured with a spectrophotometer (Helios UVG1702E, England) at wavelengths 663, 647, and 470 nm, respectively. Chlorophyll was measured according to the method of [26]. The calculation was done according to the following equations: Chlorophyll *a* = 12.70 × A663 – 2.79 × A647.

Chlorophyll *b* = 20 × A647 – 4.62 × A663

Total chlorophyll = Chlorophyll *a* + Chlorophyll *b*

Osmolyte contents

For the measurement of Total Soluble Sugar (TSS), a modified phenolsulfuric assay was used [27]. Subsamples (100 mg) of dry leaves were placed in 50 mL centrifuge tubes. 20 mL of extracting solution (glacial acetic acid: methanol: water, 1:4:15 (v/v/v)) was added to the ground tissue and homogenized for 15 sec at 16000 rpm. The homogenate was centrifuged for 10 mn and the supernatant was decanted to a 125 ml Erlenmeyer flask. The residue was resuspended in 20 mL of extracting solution and centrifuged for another 5 min. The supernatant was decanted, combined with the original extract, and made up to 100 mL with water. One mL of 5% (v/v) phenol solution and 5 mL of concentrated H_2SO_4 were added to 1 mL aliquots of SS (reconstituted with 1 mL water). The mixture was shaken and cooled to room temperature, and absorbance was recorded at 490 nm wavelength with a spectrophotometer (Pharmaspec UV-1700 model). The amount of TSS present in the extract was calculated using a standard curve prepared from graded concentrations of glucose.

Soluble Protein content (SP) was determined by the method of [28]. Briefly, the appropriate volume (from 0 - 100 μl) of the sample was aliquoted into a tube and the total volume was adjusted to 100 μl with distilled water. A 1 ml of Bradford working solution was added to each sample well. Then the mixture was thoroughly mixed by a vortex mixer. After left for 2 min, the absorbance was read at 595 nm. The standard curve was established by replacing the sample portions in the tubes with proper serial dilutions of bovine serum albumin.

Malondialdehyde (MDA) was assayed following the method of [29]. About 0.5 g of fresh leaf was ground in 0.1% trichloroacetic acid, then mixed and centrifuged at 12,000× g for 15 min to prepare for the MDA extraction. After that, 1 mL supernatant with 4 mL 0.5% thiobarbituric acid (containing 20% trichloroacetic acid) was heated at 95 ∘C for 15 min and then centrifuged at 10,000× g for 15 min. Then the sample was recorded for absorption at 600, 532 and 450 nm and MDA content was calculated.

Antioxidant compounds

For estimation of Ascorbic Acid Content (ASA), 1 g of frozen leaf tissues was homogenized in 5 mL of ice-cold 6% m-phosphoric acid (pH 2.8) containing 1 mM EDTA [30]. The homogenate was centrifuged at 20,000 × g for 15 min at 4 °C. The supernatant was filtered through a 30-μm syringe filter, and 50 μL of the filtrate was analyzed using an HPLC system (PerkinElmer series 200 LC and UV/VIS detector 200 LC, USA) equipped with a 5-μm column (Spheri-5 RP-18; 220 × 4.6 mm; Brownlee) and UV detection at 245 nm with 1.0 mL/min water (pH: 2.2) as the mobile phase, run isocratically [31].

The total phenolic (TP) content of the extract was determined by the Folin Ciocalteu method [32]. Subsamples (1 g) of fresh leaves were ground at 4 °C in 3 mL of 0.1 N HCl. After incubation at 4 °C for 20 min, the homogenate was centrifuged at 6000 g for 40 min. The supernatant was collected, the pellet was re-suspended in 3 mL of 0.1 N HCl, and centrifuged as previously. The two supernatants are mixed and constitute the crude extract of soluble phenol. The reaction mixture containing 15 μL of extract, 100 μL Folin-Ciocalteu reagents, and 0.5 mL of 20% Na_2CO_3 was incubated at 40 °C for 20 min and absorbance read at 720 nm wavelength with a spectrophotometer (Pharmaspec UV-1700 model). A standard curve was established using chlorogenic acid. TP content was expressed as mg g^{-1} fresh weight.

The Total Flavonoid Content (TFC) of crude extract was determined by the aluminum chloride colorimetric method [33]. 50 μL of crude extract (1 mg/mL ethanol) was made up to 1 mL with methanol, mixed with 4 mL of distilled water, and then 0.3 mL of 5% $NaNO_2$ solution; 0.3 mL of 10% $AlCl_3$ solution was added after 5 min of incubation, and the mixture was allowed to stand for 6 min. Then, 2 mL of 1 mol/L NaOH solution was added, and the final volume of the mixture was brought to 10 mL with double-distilled water. The mixture was allowed to stand for 15 min, and absorbance was recorded on a spectrophotometer (Pharmaspec UV-1700 model) at 510 nm wavelength. FLA content was calculated from a rutin calibration curve, and the result was expressed as g rutin equivalent per g dry weight.

Nutrient content

K, Na, Mg, and P contents in the leaf tissue of the plants were evaluated in dry, ground, and digested samples in a CEM microwave oven [34]. P was determined by colorimetry; potassium by flame photometry; sodium and magnesium by atomic absorption spectrometry [35]. Iron and zinc contents were determined by the method reported in [36]. The leaf of the jute potager was dry ashed at 450 °C for 2 hours and digested on a heat cave with 10 ml HNO3 1 M. The solution was filtrated and adjusted at 100 ml with HNO_3 at 1/100 and analyzed with an atomic absorption spectrophotometer (Rayleigh, WFX-100).

Experimental design and statistical analysis

The experiment was conducted as a factorial completely randomized design with four NaCl treatments and four levels of banana peel in four replications. Data are presented in terms of mean (± standard deviation). All data were statistically analyzed using Statistica (version 9, Tulsa, OK, USA) and first subjected to analyses of variance (ANOVA). Statistical differences between treatment means were established using the Fisher LSD test at $p < 0.05$.

Results and discussion

Influence of banana peel application and NaCl on growth, chlorophyll, leaf relative water content, and yield characteristics

Corchorus olitorius according to the different treatments (saline and banana peel) shown in Table 4. The average PH, NL, TLA, SD, LFW, LDW, and LY increased as levels of banana peel application increased and decreased as the levels of salt stress. Higher growth and yield values were obtained at 15 h^{-1} BP and non-saline irrigation: 60.1 cm, 28.1, 65.1 cm^2, 2.85 cm, 10.7 g $plant^{-1}$, 4.2 g $plant^{-1}$ and 8.3 t ha^{-1} respectively PH, NL, TLA, SD, LFW, LDW and LY. Lower values of growth and yield were recorded at unfertilized treatment (0 h^{-1} BP) and under 200 mM NaCl: 32.3 cm, 40.3, 50.5 cm^2, 2.28 cm, 5.2 g $plant^{-1}$, 1.4 g $plant^{-1}$ and 4.1 t ha^{-1} respectively PH, NL, TLA, SD, LFW, LDW and LY (Table 4). Under salt stress (200 mM NaCl) chlorophyll content was reduced by 21.58% compared to control plants (Figure 3A). The application of organic matter (at 15 h^{-1} BP) resulted in the increase of chlorophyll content with non-saline by 12.67% and under salt stress (at 200 mM NaCl) by 11.84%. The application of NPK under salt stress (at 200 mM NaCl) led to a lower effect on protecting LRWC losses and resulted in increases in the LRWC by 2.76%. While LRWC values decreased under salt stress (at 200 mM NaCl) by 17.64% in salty plants without BP, the organic matter applications (15 h^{-1} BP) to LRWC demonstrated an increase of 11% in the same conditions (Figure 3B).

Salinity in soils diminished plant growth and yield by affecting three major physiological metabolic pathways: osmotic, ionic, and oxidative stresses [37]. The addition of BP significantly ($p < 0.05$) promoted the growth and yield at different levels of saline treatment. Soil amendments with organic manures reduce the toxic effects of salinity in various plant species such as alfalfa [12]. [17] reported that the increase in plant growth and yield parameters with organic matter was mainly due to the reason more concentrated nutrients or minerals were made readily available and easily

Table 4: Effects of banana peel rates on growth and yield characters of jute potager (*Corchorus olitorius* L.) under salt stress (14 WAS).

		Growth and yield parameters						
Treatment (mM NaCl)	BP (t ha^{-1})	PH (cm)	NL	TLA (cm^2)	SD (cm)	LFW (g)	LDW (g)	LY (t ha^{-1})
Control	0	49.3 ± 0.02d	29.2 ± 0.71g	54.4 ± 2.24c	2.58 ± 0.12m	8.9 ± 0.12k	3.1 ± 0.91lm	7.4 ± 0.91kl
	NPK	52.8 ± 0.02c	32.2 ± 0.71g	57.3 ± 2.24b	2.69 ± 0.12m	9.3 ± 0.12k	3.3 ± 0.91lm	7.6 ± 0.91kl
	5	50.3 ± 0.03d	30.1 ± 0.82h	56.3 ± 3.01b	2.68 ± 0.16m	9.2 ± 0.16k	3.2 ± 0.08lm	7.5 ± 0.08kl
	10	54.7 ± 0.02c	34.9 ± 0.81g	59.5 ± 3.21b	2.77 ± 0.23m	9.8 ± 0.23k	3.6 ± 0.07lm	7.8 ± 0.07kl
	15	60.1 ± 0.04b	40.3 ± 0.93f	65.1 ± 3.33a	2.85 ± 0.41m	10.7 ± 0.41k	4.2 ± 0.11l	8.3 ± 0.11k
50	0	47.5 ± 0.03d	27.8 ± 0.88h	51.6 ± 2.67c	2.36 ± 0.21m	7.5 ± 0.21kl	2.4 ± 0.12jk	5.1 ± 0.12l
	NPK	50.8 ± 0.02d	30.2 ± 0.71h	54.3 ± 2.24c	2.41 ± 0.12m	7.7 ± 0.12kl	2.6 ± 0.91jk	5.3 ± 0.91l
	5	48.6 ± 0.06cd	28.6 ± 0.76h	53.3 ± 2.34c	2.39 ± 0.32m	7.7 ± 0.32kl	2.6 ± 0.09jk	5.3 ± 0.09l
	10	52.4 ± 0.04c	33.7 ± 0.67g	57.4 ± 2.88b	2.58 ± 0.28m	8.3 ± 0.28k	2.9 ± 0.13jk	5.6 ± 0.13l
	15	57.2 ± 0.05b	37.6 ± 0.59f	61.9 ± 3.45ab	2.64 ± 0.25m	9.5 ± 0.25k	3.4 ± 0.07lm	6.1 ± 0.07l
100	0	39.9 ± 0.02f	24.5 ± 0.62gh	48.3 ± 3.12d	2.05 ± 0.17m	5.6 ± 0.17l	1.5 ± 0.11k	4.5 ± 0.11l
	NPK	41.8 ± 0.02ef	26.2 ± 0.71hi	50.2 ± 2.24d	2.16 ± 0.12m	5.9 ± 0.12l	1.8 ± 0.91k	4.6 ± 0.91l
	5	40.8 ± 0.07f	25.2 ± 0.73i	49.3 ± 2.88d	2.14 ± 0.44m	5.8 ± 0.44l	1.8 ± 0.09k	4.6 ± 0.09l
	10	42.3 ± 0.07e	28.6 ± 0.75h	52.9 ± 4.01c	2.22 ± 0.59m	6.2 ± 0.59l	1.9 ± 0.14k	4.8 ± 0.14j
	15	46.8 ± 0.03de	32.1 ± 0.82f	56.7 ± 3.45bc	2.31 ± 0.38m	6.8 ± 038l	3.1 ± 0.06lm	5.2 ± 0.06l
200	0	32.3 ± 0.06g	20.5 ± 0.78j	44.2 ± 2.66e	1.88 ± 0.58m	4.05 ± 0.58l	0.8 ± 0.05ln	2.9 ± 0.05jk
	NPK	33.8 ± 0.02g	22.2 ± 0.71i	46.3 ± 2.24de	1.96 ± 0.12m	4.2 ± 0.12l	0.96 ± 0.91n	3.3 ± 0.91lm
	5	32.7 ± 0.7g	21.6 ± 0.84ij	45.5 ± 2.33e	2.07 ± 0.62m	4.1 ± 0.62l	0.93 ± 0.82n	3.2 ± 0.11lm
	10	34.5 ± 0.03g	24.4 ± 0.79i	47.4 ± 3.04d	2.19 ± 0.49m	4.5 ± 0.49l	1.2 ± 0.12m	3.6 ± 0.12lm
	15	38.7 ± 0.04f	28.1 ± 0.76h	50.5 ± 3.23d	2.28 ± 0.76m	5.2 ± 0.76l	1.4 ± 0.11n	4.1 ± 0.11l
Two-way ANOVA results								
Salt stress (SS)		**	**	**	NS	*	NS	*
Banana peel (BP)		*	*	*	*	*	*	*
Interaction BP x SS		*	*	*	NS	*	NS	*

Values shown are means (*n* = 5) ± SD; within columns, means followed by different letters are significantly different ($p < 0.05$).
**, *significant at 1 and 5% probability levels, respectively, NS: Not Significant

absorbable by the receiving plants leading to faster growth and development. The organic matter (BP) may affect plant growth and yield as a source of growth promoters, auxin, vitamins, and amino acids which act on the vegetative growth, yield, and quality of the plant product [38,39]. The most negative leaf water and stem water potential values were observed in plants subjected to water and salinity stress, because passive dehydration, as well as the accumulation of salt, plays a role in decreasing the water potential in leaves [22,40].

Even though the application of NaCl decreased the photosynthetic pigment contents of the seedlings, the application of organic matter limited those decreases. [41], reported that the increased chlorophyll accumulation in organic fertilizers, even at a decreased rate, could be the result of the cooperative effects of the consortium, which facilitates plant N, P, and K uptake better, resulting in increased chlorophyll accumulation. [42], reported that organic fertilizer can increase the pigment of chlorophyll concentration, leaf relative water content, growth, and yield parameters in *Talinum triangulare* (jacq.) Willd.

Effects of banana peel application and salinity on osmolytes and antioxidant compounds

SP and TSS content were significantly affected by BP and NaCl treatment ($p < 0.05$). Application of BP significantly increased SP and TSS content under salt stress and the maximum content was produced at 15 h^{-1} BP and 200 mM NaCl (46.7 g kg^{-1} and 82.1 g kg^{-1} respectively) and the lowest value obtained at control (Figures 1A, 1B). The salt stress x banana peel interaction was significant ($p < 0.05$) at 15 h^{-1} BP and 200 mM NaCl (Figure 1). MDA content was significantly increased as the levels of salt stress increased ($p < 0.05$). On the contrary, the application of BP reduced MDA content. 200 mM NaCl without BP showed a higher content of MDA (5.15 nmol g^{-1} FW) than other treatments at 100 and 50 mM NaCl with 4.04 and 1.83 nmol g^{-1} FW respectively (Figure 1C).

The NaCl treatments at 50, 100, and 200 nM decreased ASA content by 9.13%, 19.49%, and 31.35%, respectively, when compared to salt stress alone with control. Application of BP from 0 to 15 t ha^{-1} increased ASA content without salt stress at 3.21% and increased ASA content at 50, 100, and 200 mM NaCl to 3.33%, 7.23%, and 7.37% respectively (Figure 2A). TP and TFC of jute do not significantly change at low NaCl levels (50 mM NaCl), while they significantly increase with the increase of NaCl concentrations of the nutrient solution from 100 to 200 mM NaCl. Application of BP increased significantly TP and TFC contents at 5, 10, and 15 t ha^{-1} levels with or without NaCl treatment (Figure 2B and 2C). The highest amount of TP and TFC were observed at 15 t ha^{-1} BP under 200 mM NaCl (466.1 mg GAB g^{-1} MS and 73.5 mg QE g^{-1} MS respectively).

The osmotic substances, such as SP and TSS that were regulated by fertilizers, could enhance water uptake by increasing the positive osmotic potential in soil, which could trigger chemical signaling that leads to increased stomatal aperture and photosynthetic rate [43,44]. Increased BP supplementation proved much more effective in improving

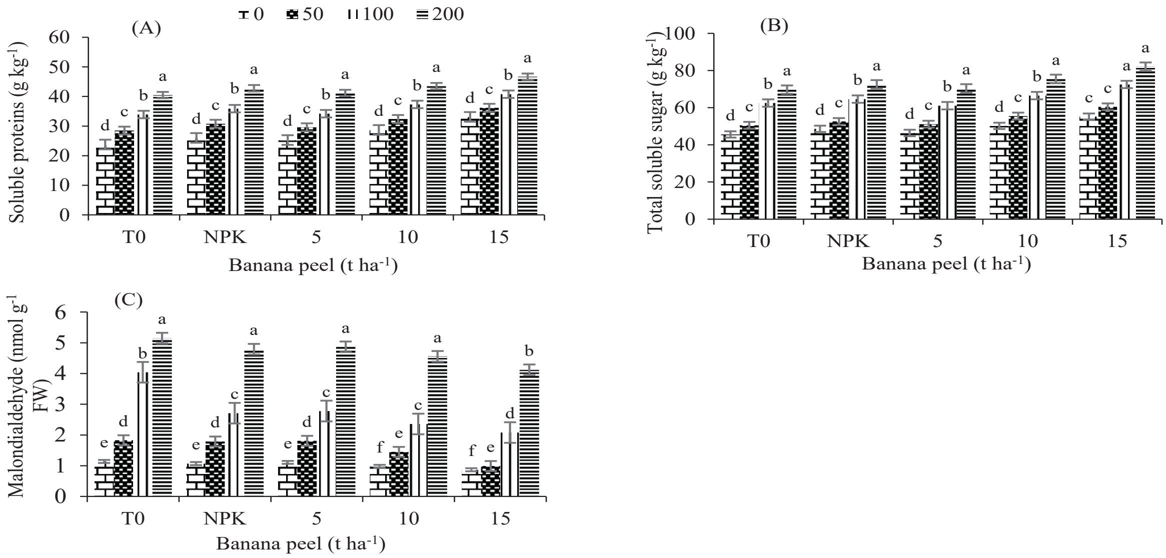

Figure 1: : Effects of banana peel rates on osmolytes of jute potager (*Corchorus olitorius* L.) under salt stress (50, 100 and 200 mM NaCl) at 14 WAS. Soluble proteins (A), total soluble sugars (B) and malondialdehyde (C). Bars are means (n = 5) ± SD. Means followed by different letter are significantly different (p < 0.05).

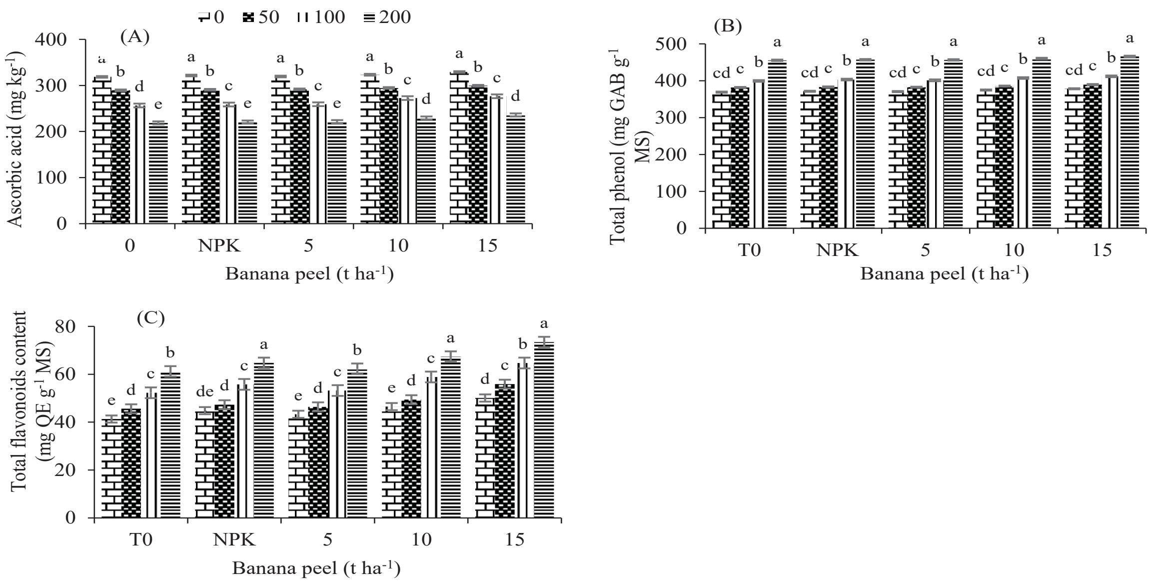

Figure 2: : Effects of banana peel rates on antioxidant compound of jute potager (*Corchorus olitorius* L.) under salt stress (50, 100 and 200 mM NaCl) at 14 WAS. Ascorbic acid (A), total phenol (B) and total flavonoid content (C). Bars are means (n = 5) ± SD. Means followed by different letter are significantly different (p < 0.05).

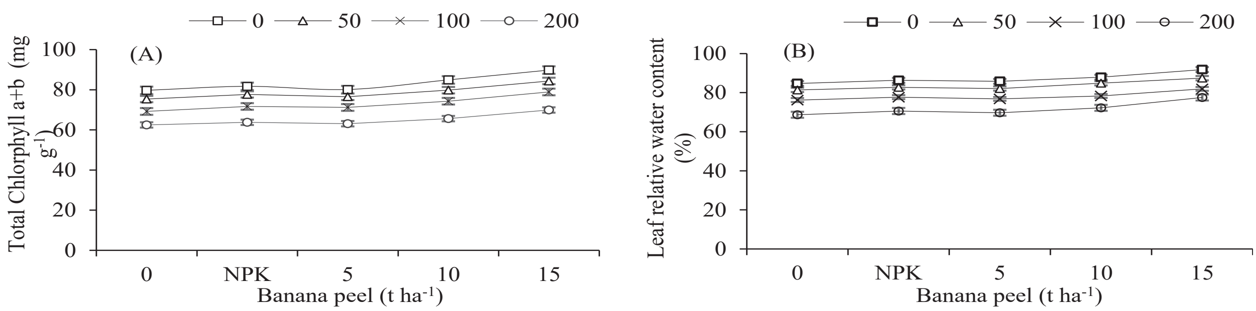

Figure 3: Effects of banana peel rates on total chlorophyll and leaf relative water content of jute potager (*Corchorus olitorius* L.) under salt stress (50, 100, and 200 mM NaCl) at 14 WAS. Total chlorophyll (A) and leaf relative water content (B). Bars are means (n = 5) ± SD. Means followed by different letters are significantly different (p < 0.05).

the osmolyte accumulation reflected in the maintenance of growth and hence the amelioration of salinity stress-mediated growth retardation. Increased accumulation of SP and TSS significantly prevents salinity-induced photosynthetic inhibition [37]. Tissue concentration of compatible solutes is maintained either by irreversible synthesis of the compounds or by a combination of synthesis and degradation, and the accumulation of osmolytes is proportional to the external osmolarity [45]. Osmolytes protect the structure and the osmotic balance of cells by maintaining the water influx [46]. Accumulated osmolytes assist in quick growth recovery after stress release [47]. BP application in plants grown declined the MDA levels under salt stress. MDA, which plays the role of a cellular toxicity bioindicator, is a well-known oxidation that emerges from lipid peroxidation during oxidative stress [48]. In this study, the lipid peroxidation of jute increased with salt stress. At the same time, MDA organic matter contents, especially in the BP treatment group, were lower than the contents of seedlings in the NPK treatment group. The results showed that the BP treatments reduced MDA levels, presenting a favorable effect in reducing the oxidative stress that emerged from salt stress.

The reports describing the BP availability-induced regulation of the antioxidant system are scanty and further studies can be handy in understanding the actual underlying mechanisms. Salinity stress reduces the redox homeostasis thereby hampering the redox-dependent cellular functions like electron transport and energy generation [45,49]. BP availability imparted a beneficial impact on the synthesis of secondary metabolites including phenols and flavonoids. Secondary metabolites including phenols and flavonoids are involved in the regulation of auxin transport, photoprotection, mechanical support, seed dispersal, and protection against insect herbivory [42,50]. Secondary metabolites including flavonoids prevent oxidative damage by inhibiting the formation of ROS and protect cellular functioning by scavenging radicals like superoxide [37].

Effects of banana peel application and salinity on leaf nutrient content

Saline irrigation water and BP addition significantly affected leave tissue in all ionic concentrations (Table 5). The increasing BP level from 0 to 15 t ha^{-1} with non-saline irrigation, significantly increased P, Zn, Mg, K, and Iron in leave from 19.8 to 31.1 g kg^{-1}, 66.2 to 75.3 mg kg^{-1}, 338.7 to 386.1 mg kg^{-1}, 4365.6 to 5456.2 mg kg^{-1}, 87.6 to 98.6 mg kg^{-1} respectively and significantly decreased Na from 5.33 to 3.89 g kg^{-1}. Application of BP at 15 t ha^{-1} with saline irrigation at 200 mM NaCl, showed an increase at 49.1%, 14.63%, 19.47%, 20.68%, and 12.06% respectively in P, Zn, Mg, K, and Iron and reduced at 28.44% in Na. The salt stress x BP interaction had a significant ($p < 0.05$) effect on Na, P, Mg, Zn, K, and Iron in leave tissue. The Na concentrations in the leaves increased with saline irrigation water whereas P, Mg, Zn, K, and Iron uptake by leaves reduced with saline irrigation and irrespective of the BP fertilization.

Table 5: Effects of banana peel rates on mineral components of jute potager (*Corchorus olitorius* L.) under salt stress (14 WAS).

		Leaf mineral components					
Treatment (mM NaCl)	BP (t ha^{-1})	P (g kg^{-1})	Zn (mg kg^{-1})	Mg (mg kg^{-1})	K (mg kg^{-1})	Iron (mg kg^{-1})	Na (g kg^{-1})
Control	0	19.8 ± 0.02r	66.2 ± 0.71l	338.7 ± 2.24e	4365.6 ± 4.12b	87.6 ± 0.12i	5.33 ± 0.11tu
	NPK	22.8 ± 0.02r	68.7 ± 0.71l	347.4 ± 2.24e	4468.6 ± 4.12ab	89.9 ± 0.12i	5.07 ± 0.21tu
	5	21.3 ± 0.03r	67.1 ± 0.82l	351.3 ± 3.01e	4460.4 ± 4.16ab	88.8 ± 0.16i	5.21 ± 0.18tu
	10	25.7 ± 0.02q	70.9 ± 0.81l	368.5 ± 3.21e	4891.2 ± 4.23a	93.2 ± 0.23h	4.91 ± 0.17u
	15	31.1 ± 0.04q	75.3 ± 0.93k	386.1 ± 3.33e	5456.2 ± 3.41a	98.6 ± 0.41h	3.89 ± 0.21u
50	0	15.5 ± 0.03s	57.8 ± 0.88m	302.6 ± 2.67f	3612.5 ± 4.21bc	76.5 ± 0.21k	8.45 ± 0.12t
	NPK	17.8 ± 0.02rs	59.2 ± 0.71m	313.3 ± 2.24f	3742.6 ± 4.12b	77.1 ± 0.12k	7.51 ± 0.61t
	5	16.6 ± 0.06s	58.6 ± 0.76m	321.3 ± 2.34f	3703.6 ± 3.32b	77.9 ± 0.32k	7.75 ± 0.59t
	10	18.4 ± 0.04r	60.7 ± 0.67m	334.4 ± 2.88f	3918.5 ± 4.82b	79.7 ± 0.28k	6.68 ± 0.53t
	15	25.2 ± 0.05q	64.6 ± 0.59lm	349.5 ± 3.45f	4127.5 ± 4.51b	83.4 ± 0.25j	5.47 ± 0.047tu
100	0	12.9 ± 0.2s	49..5 ± 0.62n	241.3 ± 3.12g	3017.5 ± 4.17c	68.6 ± 0.17l	11.22 ± 0.51s
	NPK	13.8 ± 0.02s	50.2 ± 0.71n	258.3 ± 2.24g	3187.6 ± 3.12c	69.6 ± 0.12l	10.31 ± 0.63st
	5	12.8 ± 0.07s	51.6 ± 0.73n	244.3 ± 2.88g	3122.1 ± 3.44c	69.5 ± 0.44m	10.63 ± 0.79st
	10	14.3 ± 0.07s	53.6 ± 0.75n	262.9 ± 4.01g	3301.5 ± 3.59c	71.7 ± 0.59k	9.13 ± 0.14t
	15	18.8 ± 0.03r	57.1 ± 0.82m	296.7 ± 3.45g	3601.5 ± 3.38bc	75.6 ± 038k	7.95 ± 0.46t
200	0	8.5 ± 0.06t	38.5 ± 0.78p	216.2 ± 2.66g	2382.7 ± 2.58d	56.1 ± 0.58mn	19.51 ± 0.55r
	NPK	10.8 ± 0.02st	40.2 ± 0.71op	228.3 ± 2.24g	2510.6 ± 2.12d	58.2 ± 0.12m	18.72 ± 0.41r
	5	9.7 ± 0.72t	39.6 ± 0.84p	221.6 ± 2.33g	2492.4 ± 2.62d	57.1 ± 0.62m	18.37 ± 0.61r
	10	12.5 ± 0.03s	42.4 ± 0.79o	242.4 ± 3.04g	2658.5 ± 2.49d	59.2 ± 0.49m	16.55 ± 0.52s
	15	16.7 ± 0.04s	45.1 ± 0.76o	268.5 ± 3.23g	3004.1 ± 2.76c	63.8 ± 0.76m	13.96 ± 0.41s
Two-way ANOVA results							
Salt stress (SS)		*	*	*	*	*	*
Banana peel (BP)		*	*	*	*	*	*
Interaction BP x SS		*	*	*	*	*	*

Values shown are means ($n = 5$) ± SD; within columns, means followed by different letters are significantly different ($p < 0.05$).
**, * significant at 1 and 5% probability levels, respectively, NS not significant.

Modification of organic fertilizers has assisted in the reduction of sodium and chlorine content in leaves regardless of saline and non-saline water irrigation and balanced the sodium-induced toxicity [51,52]. It is reported that the addition of organic fertilizer declined the uptake of sodium and chlorine ions by enhancing the availability of other crucial ions such as potassium, zinc, iron, nitrogen, and phosphorus for the whole plant [42]. The reduction in the potassium percentage in the leaves from the reverse relationships between it and sodium concentration and an increase of the sodium concentration in the soil solution by the irrigation with salty brings the removal of potassium from the absorption area in the roots, the deterioration in the balance of nutrition and reduction of its absorption [53,54] mentioned that the addition of organic matter declines the sodium percentage because organic matter stores a part of sodium in the form of a Na-Organic compound. Similarly [12], experimented to study the soil amendments with organic matter significantly increased the nutrient uptake of rice cultivars under saline conditions leading to plant salt tolerance improvement.

From this study, 15 t ha^{-1} of BP was better for growth, leaf yield, ascorbic acid, total phenolic, leaf relative water content, and ions content than other treatments for jute production.

Conclusion

Organic fertilizers are important for the environment and represent a favorable and renewable cheap source for agricultural practices. The application of banana peel under salt stress appeared to be favorable for the agro-morphological, physiological, and chemical processes of the jute (*Corchorus olitorius* L.). From the results presented herein, it could be concluded that the application of banana peel could effectively increase the growth and yield parameters, TFC, ASA content, LRWC, chlorophyll, P, Iron, Zn, K and Mg accumulation, in addition to reducing SP, TP, TSS, MDA content and Na accumulations of jute (*Corchorus olitorius* L.) plants, under salt stress and the best result was observed at 15 t ha^{-1}. Interestingly, in the current study, even though all of the BP components improved salt tolerance, the manure effect was more evident than that of the other organic manures under salt stress. Therefore, it could be recommended to use banana peel as it can effectively improve metabolic and physiological processes in jute (*Corchorus olitorius* L.) plants which might lead to increased salt stress tolerance.

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