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Performance of *Theobroma cacao* (L.) Seedlings Irrigated with Water from Different Sources

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Abstract: Reliability of six irrigation water sources (stream, borehole, river, well, rain and sea) for raising cacao (*Theobroma cacao* L.; varieties F_3 Amazon and Amelonado) seedlings was investigated, using 6×2 factorial experiment, replicated three times in completely randomized design. Plant vigor was assessed with height growth; stem girth, number of leaves, leaf area and canopy spread data taken at 3 weeks interval. Due to declining growth rate, seawater-irrigated seedlings' biomass production, percentage tissue Nitrogen (N) and percentage tissue Phosphorus (P) were evaluated at 9 Weeks after Sowing (WAS) while the same parameters were determined at 24 WAS for seedlings irrigated with water from other sources. Only stream- and rain- waters had pH < 8 while seawater had Electrical Conductivity (EC_{25}) that was over 200 times higher than for each of the other sources. Seedling performance was best with stream water and poorest with seawater. Performance differences among seedlings irrigated with water from borehole, river, well and rain were insignificant ($p<0.05$) and similar to those irrigated with stream-water. Amelonado seedlings irrigated with water from borehole produced the highest fresh shoot biomass (60.38 g/pot) while river-water irrigated F_3 Amazon had the highest fresh root biomass (11.09 g/pot). The fresh shoot and root weights of seawater treated seedlings were less than for each of the other sources. On drying, sea-watered F_3 Amazon seedling recorded highest shoot and root weights' percentage losses (67.9 and 77.3%, respectively). Irrigation water alkalinity (pH) was inversely related to seedling leaf expansion while salinity (EC_{25}) influenced biomass production and nutrient uptake negatively and percentage moisture positively, but had no influence on nutrient content in plant tissue. It was evident that water from the various sources apart from sea could be relied upon for use in cacao nurseries.

Key words: *Theobroma cacao*, irrigation water sources, salinity tolerance, electrical conductivity, F_3 Amazon, Amelonado

INTRODUCTION

Nursery is an important stage in the successful establishment of cocoa plantations. Cacao seedlings should be raised for 5-7 months before transplanting on the permanent sites (Mossu, 1992; Obatolu *et al*., 2000). Intensive management of soil/cacao agro-ecological system is required at the nursery stage so as to enhance resource use efficiency and minimize potentially harmful effects of inappropriate water and/or nutrient element uptake since young cacao plants are very sensitive to nutrient imbalance and toxicity (Wood and Lass, 1985). Yet, the need to site nurseries close to a running water source has deprived thousands of cocoa farmers the opportunity of raising their own seedlings and there is a need to expand the location of cacao nurseries beyond riverbanks.

Water collected from streams, rivers or dams to wet seedlings is not likely to cause problem, but when the source is a well or a borehole, the salinity level can be dangerously high as to cause damage to the plant (Gordon, 1988; Kuiper and Probos, 2005). Michael (1999) agreed that high salt content of seawater could make it unfavorable for irrigating crops. However, Mass and Hoffman (1977), Lambert and Turner (2000) reported a spectrum of responses of different crops to salinity and showed that differences among varieties should be considered when evaluating salt tolerance since many crops are developed from diverse genetic base.

Very little work has been done on the effect of salinity on the performance of cacao seedlings. In this work, we tested the hypothesis that the water available (from different sources) for irrigating cacao seedlings has different salinity levels and could not support crop

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performance to the same extent. Patel *et al*. (2004) observed significant differences among rice genotypes for different characters, due to different levels of salinity. Yet, with a view to enabling cocoa farmers to raise their own seedlings where and when it is convenient for them, it is imperative to determine the possibility of using several water sources in raising different varieties of cacao seedlings. Hence, the research work reported here aimed at evaluating the effect of various irrigation water sources on the growth, biomass production and N and P nutrition of cacao seedlings. It was envisaged that the effect of the interaction between the water sources and cacao varieties on seedling performance would be elucidated.

MATERIALS AND METHODS

The experiment was carried out in a glass house at Cocoa Research Institute of Nigeria (CRIN) headquarters in Ibadan, Nigeria, between February and September 2004. It was a factorial combination of six water sources (rain, stream, borehole, well, river and sea) and two cocoa varieties (F_3 Amazon and Amelonado) in a Completely Randomized Design (CRD) with three replications.

The experimental soil (an Alfisol, Olorunda series) was collected beside the CRIN glass house at a depth of 0-15 cm using a soil auger. It was air-dried and made to pass through 2 mm sieve (to remove stones, roots and other debris) before 5 kg sub-samples were weighed into 36 polybags (35×25 cm in size) perforated at the base. The Electrical Conductivity at 25°C (EC_{25}) and pH of water from each of the irrigation water sources were determined. The seedlings of each cocoa variety were pre-germinated by wetting with distilled water for three weeks prior to transplanting into the polythene bags. The bags were watered as at when necessary to keep the moisture content of the soil at 60% Field Capacity (FC).

Data collection started at 3rd Week after Transplanting (WAT) and continued at 3 week intervals for 6 months, during which growth parameters (plant height, stem girth, number of leaves, leaf area and canopy spread) were measured. Vernier caliper and an area meter (Vista MK 2) were used for stem girth and leaf area measurements, respectively. Two measurements of the canopy spread were taken diagonally with metre rule and then multiplied by each other.

At the end of six months of growth, the polythene bags were torn apart and whole seedlings (with roots intact/undamaged) thoroughly washed with distilled water. They were subsequently partitioned into shoots and roots and fresh weights recorded. Dry weights were also recorded after drying the plant samples to a constant weight at 75°C for 48 h. The milled leaves were wet digested using nitric acid (HNO_3) and perchloric acid ($HClO_4$) mixture of 2:1 ratio for the determination of total N and P tissue contents by methods of Bremner (1965) and Cavell (1995). Total N and organic C were determined in the pre-cropping soil sample by Kjeldahl and the Walkley and Black procedures, respectively. Available P was determined by Bray P-1 method (Bray, 1945; Bray and Kurtz, 1945) while the cations were extracted with neutral normal NH_4OAC. Potassium in the extract was determined by flame photometry while Mg, Ca and other exchangeable bases were determined by atomic absorption spectrophotometry. Soil pH was measured using a 1:2 soil/water suspension ratio.

The mean values of all parameters measured were determined and subjected to Analysis of Variance (ANOVA). The treatment means were separated using the Least Significance Difference (LSD) concept. Correlation analysis was also carried out to evaluate the relationship among the growth, yield and nutrient content parameters.

RESULTS AND DISCUSSION

Soil analysis: The result of the physico-chemical analysis of the soil used (Table 1) showed that it was slightly acidic (pH in H_2O = 6.6). This was observed suitable in line with the recommendation of pH 6.5 (Mossu, 1992) for optimum growth of cocoa plants. Considering the Critical Levels (CL) of N, P and K (1.8 g kg^{-1}, 0.13 mg kg^{-1} and 1.20 cmol kg^{-1}, respectively) for raising cacao seedlings (Wessel, 1971), the soil had quite high amounts of N and P but deficient in K. The amounts of Ca and Mg in the soil showed that both nutrients were below CL of 0.30 and 0.20 cmol kg^{-1}, respectively (Wessel, 1971).

Table 1: Physico-chemical properties of the soil used for the study

Property	Value
pH (H_2O)	6.60
Organic C (g kg^{-1})	25.80
Total N (g kg^{-1})	5.40
Available P (mg kg^{-1})	44.75
Base saturation (%	67.21
$EC_{(25)}$ sm^{-1}	2.20
Exchangeable bases (cmol kg^{-1})	
Ca	0.24
Mg	0.14
K	0.20
Na	1.22
CEC	
Micronutrients (mg kg^{-1})	
Mn	68.00
Cu	57.00
Fe	2.80
Zn	3.70
B	6.80
Sand (g kg^{-1})	792.00
Silt (g kg^{-1})	174.00
Clay (g kg^{-1})	34.00

Water analysis: Actual values of pH and EC_{25} for the different irrigation water sources tested are given in Table 2 while the mean, minimum and maximum values form part of the summary of several data presented in Table 3. It is evident that water from four of the six sources (sea, well, borehole and river) were alkaline with pH greater than 8. The water from the six sources had their degree of alkalinity in the order: sea>well>borehole> river>stream>rain. Apart from rain and stream, the pH of the other sources of water revealed the presence of Ca and Mg carbonate which could make certain other elements unavailable and often times, damage the soil structure by reducing water infiltration and drainage (Michael, 1999). Unlike pH, the EC_{25} of the water from the six sources showed marked differences between sea and others. The EC_{25} of seawater was over 208 times higher than that of well water, which invariably had the next highest EC_{25} value. The salinity of water with EC_{25} <2500 sm^{-1} is regarded as low and could be used for irrigating most crops with little likelihood of salinity problem (Brooker, 1991). However, when EC>22,500 sm^{-1} such salinity is high and not suitable for irrigation under ordinary or normal conditions but may be used occasionally under special circumstances (Michael, 1999).

Table 2: pH and Electrical Conductivity (EC_{25}) of the six forms of irrigation water tested

Water sources	pH	EC_{25} (dS m^{-1})
Stream	7.92	0.06
Borehole	8.07	0.06
River	8.06	0.06
Well	8.20	0.12
Rain	7.07	0.043
Sea	8.33	25.00
LSD (5 %)	0.40	9.28

dS m^{-1}= Siemen per metre, S.I. unit for Electrical Conductivity, formerly milliohm per centimeter, mmhos cm^{-1}

Growth parameters: Table 3 and 4 show data on plant height, stem girth, area and number of leaves and canopy spread of the seedlings. There were increases with time in these growth parameters for all the seedlings (under the various treatments) at the early stage, probably due to the fact that the seedlings depended on their cotyledons for food at this stage and required only little nutrients from the soil. Meanwhile, at the 3rd WAT, the leaves of sea water- treated seedlings started dying back and continued until after 6th WAT when they eventually died. This seemed to be as a result of the effect of toxicity of the saline seawater. However, there was no significant

Table 3: Summary (minimum, maximum and mean) of the chemical properties (pH and electrical conductivity, EC) of the irrigation water forms as well as growth, nutrition and biomass production parameters of cacao seedlings

Parameter	Minimum	Maximum	Mean±SE
Irrigationwater-			
pH	7.07	8.33	7.94±0.12
Electrical conductivity, EC (dS m^{-1})	0.04	25.00	4.22±2.80
Number of leaves –			
at the rate of age of 6 weeks	7.00	9.00	7.42±0.19
at the rate of age of 21 weeks	14.00	23.00	17.30±1.03
Leaf area (cm^2 $plant^{-1}$)-			
at the rate of age of 6 weeks	19.60	27.56	23.31±0.81
at the rate of age of 21 weeks	66.99	87.66	79.05±2.45
Canopy spread (cm^2 $plant^{-1}$) –			
at the rate of age of 6 weeks	401.34	969.62	622.71±44.01
at the rate of age of 21 weeks	2263.04	2962.84	2697.07±72.16
Plant height (cm $plant^{-1}$)–			
at the rate of age of 6 weeks	17.20	22.25	19.66±0.48
at the rate of age of 21 weeks	39.83	55.77	47.38±1.50
Stem girth (cm $plant^{-1}$)–			
at the rate of age of 6 weeks	0.40	0.57	0.49±0.02
at the rate of age of 21 weeks	0.79	1.07	0.95±0.03
Fresh shoot (g pot^{-1})	5.92	60.38	41.28±5.30
Dry shoot (g pot^{-1})	1.90	22.20	14.99±1.93
Fresh root (g pot^{-1})	2.20	11.09	8.89±0.90
Dry root (g pot^{-1})	0.50	5.60	3.56±0.45
Root-root dry matter ratio	0.18	0.33	0.25±0.01
moisture in shoot (%)	60.10	67.90	64.06±0.75
moisture in root (%)	46.50	77.30	61.83±2.42
P in shoot (%)	0.31	0.43	0.36±0.01
N in shoot (%)	4.20	4.97	4.44±0.08
P uptake (mg pot^{-1})	1.75	20.64	12.83±1.68
N uptake (mg pot^{-1})	21.00	243.04	158.70±20.04

Table 4: Growth of cacao seedlings under irrigation with water from different sources

Water source	Girth (cm) F_3 Amazon	Girth (cm) Amelonado	Plant height (cm) F_3 Amazon	Plant height (cm) Amelonado	No. of leaves F_3 Amazon	No. of leaves Amelonado	Leaf area (cm^2) F_3 Amazon	Leaf area (cm^2) Amelonado	Canopy spread (cm^2) F_3 Amazon	Canopy spread (cm^2) Amelonado
6 Weeks After Transplanting (WAT)										
Stream	0.47	0.57	19.27	19.14	7.00	9.00	26.25	24.03	739.37	969.62
Borehole	0.48	0.54	18.75	21.72	7.00	8.00	24.74	20.27	512.22	558.69
River	0.50	0.55	19.42	21.33	7.00	8.00	25.74	21.66	671.11	616.53
Well	0.51	0.51	18.58	21.07	8.00	7.00	22.06	21.58	626.13	556.75
Rain	0.48	0.49	19.92	22.25	7.00	7.00	27.56	26.34	704.33	689.97
Sea	0.41	0.40	17.23	17.20	7.00	7.00	20.05	19.6	426.50	401.34
LSD (5%)	0.03	0.06	0.85	1.74	0.37	0.74	2.57	2.29	110.04	173.91
21 Weeks After Transplanting (WAT)										
Stream	0.79	0.95	55.77	46.70	19.00	16.00	85.72	82.49	2824.33	2577.50
Borehole	1.07	1.01	47.23	54.00	14.00	23.00	86.43	86.06	2687.67	2263.04
River	0.96	0.96	45.13	47.70	20.00	21.00	79.57	87.66	2850.49	2490.55
Well	0.89	0.90	42.70	39.83	15.00	14.00	70.23	66.99	2962.84	2518.40
Rain	1.04	0.95	46.00	48.70	14.00	17.00	71.73	73.65	2908.13	2887.72
Sea	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
LSD (5%)	0.11	0.04	4.48	4.97	2.82	3.62	7.42	8.60	101.56	219.77

ND = Not Determined

Table 5: Correlation coefficients relating pH and Electrical Conductivity (EC) of irrigation water forms, growth as well as nitrogen and phosphorus nutrition parameters after (a) six weeks and (b) twenty-one weeks of cacao seedlings growth

	H_2O-sources pH	H_2O-sources EC	No. of leaves	Stem girth	Plant height	Leaf area	Canopy Score	P (%)	N (%)	P- uptake	N- uptake
After 6 weeks of growth											
H_2O-] pH	1	0.43	0.22	-0.15	-0.51	-0.76**	-0.47	-0.22	-0.32	-0.51	-0.51
sources] EC		1	-0.29	-0.80**	-0.69**	-0.58*	-0.64*	-0.07	-0.39	-0.86**	-0.90**
No. of leaves			1	0.89**	0.95**	0.94**	0.88**	-0.12	-0.13	0.25	0.26
Stem girth				1	0.64*	0.95**	0.95**	-0.02	0.20	0.72**	0.75**
Plant height					1	0.98**	0.96**	0.35	0.45	0.83**	0.83**
Leaf area						1	0.96**	0.13	0.30	0.47	0.49
Canopy score							1	0.07	0.04	0.54	0.53
P (%)								1	0.68**	0.34	0.24
N (%)									1	0.37	0.37
P- uptake										1	0.99**
N- uptake											1

	H_2O-sources pH	H_2O-sources EC	No. of leaves	Stem girth	Plant height	Leaf area	Canopy Score	P (%)	N (%)	P- uptake	N- uptake
After 21 weeks of growth											
H_2O-] pH	1	0.43	0.22	-0.25	-0.15	0.28	-0.44	-0.22	-0.32	-0.51	-0.51
sources] EC		1	-0.33	-0.41	-0.61*	-0.53*	-0.03	-0.07	-0.39	-0.86**	-0.90**
No. of leaves			1	0.89**	0.95**	0.62*	0.88**	0.09	-0.17	0.52	0.54
Stem girth				1	0.94**	0.95**	0.95**	-0.27	0.39	-0.30	-0.12
Plant height					1	0.98**	0.96**	0.30	0.03	0.35	0.29
Leaf area						1	0.96**	0.13	0.10	0.12	0.10
Canopy score							1	0.02	-0.05	0.02	0.00
P (%)								1	0.68**	0.34	0.24
N (%)									1	0.37	0.37
P- uptake										1	0.99**
N- uptake											1

n = 12, *, ** r-values significant at p<0.05 and p<0.01, respectively

Table 6: The biomass production of cacao seedlings under irrigation with water from different sources

Irrigation water Sources	Shoot Fresh weight (g pot^{-1}) F_3Amazon	Shoot Fresh weight (g pot^{-1}) Amelonado	Shoot Dry weight (g pot^{-1}) F_3 Amazon	Shoot Dry weight (g pot^{-1}) Amelonado	Root Fresh weight (g pot^{-1}) F_3 Amazon	Root Fresh weight (g pot^{-1}) Amelonado	Root Dry weight (g pot^{-1}) F_3 Amazon	Root Dry weight (g pot^{-1}) Amelonado
Stream	50.07	50.18	17.00	16.90	10.24	10.04	4.30	3.40
Borehole	50.04	60.38	16.50	22.00	9.52	10.26	2.90	4.40
River	40.60	50.41	16.20	19.30	11.09	10.46	4.00	5.60
Well	60.06	30.48	22.20	11.90	10.06	10.02	4.40	3.50
Rain	40.24	50.63	15.00	18.90	10.19	10.35	4.20	4.80
Sea	5.92	6.30	1.90	2.10	2.20	2.30	0.50	0.70
LSD (5%)	17.10	18.03	6.20	6.60	3.02	2.96	1.38	1.55

Table 7: Percentage moisture content of fresh cacao seedlings under irrigation with water from different sources

Irrigation water Sources	Moisture in shoot (%)		Moisture in root (%)	
	F_3 Amazon	Amelonado	F_3 Amazon	Amelonado
Stream	66.00	66.30	58.20	66.10
Borehole	67.00	63.60	69.50	57.10
River	60.10	61.70	63.90	46.50
Well	63.00	61.00	56.30	65.10
Rain	62.70	62.70	58.80	53.60
Sea	67.90	66.70	77.30	69.60
LSD (5%)	2.73	2.16	7.38	8.02

difference between the two varieties of the crop in their response to the irrigation water sources throughout the experimental period. Notwithstanding, seedlings irrigated with well water had their leaves dying back as from the 12th WAT. This is also probably due to the slightly high EC_{25} of the well water.

Throughout the assessment period, F_3 Amazon maintained a comparatively better (but insignificantly different) performance than the Amelonado. The results of correlation analysis (Table 5) revealed positive relationships among the growth parameters irrespective of the variety used.

Biomass production: The details of the effect of the treatments (water sources and variety) on biomass production by the seedlings are given in Table 6. Both the fresh and dry weights of the shoots and roots of seawater treated seedlings were significantly different ($p \leq 0.05$) from those of the seedlings irrigated with water from the other sources. Amelonado seedlings irrigated with water from borehole had the highest fresh shoot weight (60.38 g/pot) while F_3 Amazon irrigated with river water had highest fresh root weight (11.09 g/pot). The highest dry shoot and root weights of 22.2 g/pot and 5.6 g/pot were produced by F_3 Amazon irrigated with well water and Amelonado irrigated with river water, respectively.

Percentage weight loss: Data on the percentage weight (moisture) loss from the seedlings is summarized in Tables 3 and 7. Seawater irrigated F_3 Amazon had the highest shoot and root percentage losses of 67.9 and 77.3%, respectively. This is most probably due to the fact that they were still succulent at the 6th week stage when they had to be weighed for the determination of biomass production. However, there was no significant difference ($p \leq 0.05$) in the percentage weight losses in the shoot of all the seedlings. Steward (1965) and Michael (1999) explained that high salt content of irrigated water reduces the ability of cacao seedlings to photosynthesis and convert absorbed water/nutrients into biomass production.

Nitrogen and phosphorus nutrition: The N and P contents in the cacao seedling leaves are presented in Tables 3 and 8. The respective uptake values are also provided. According to Wessel (1971), > 2.00 and >0.18% are the recommended or normal cacao seedling tissue contents of N and P, respectively. There were reasonably high contents of N (4.20-4.97%) and P (0.31-0.43%) in the leaves of the cacao seedlings irrespective of the irrigation water source. It is obvious that the minor differences in the nutrient contents in the leaves of plants of the same age might be due to differences either in nutrient supply or light intensity rather than from toxicity occasioned by high salt content in the soil or water used. This is in agreement with the submission of Wessel (1971).

Irrigation water forms' properties and cacao seedlings' performance parameters relations: Tables 5 and 9 show that correlation among the properties of irrigation water forms measured [degree of acidity (pH) and electrical conductivity (EC_{25})] was not significant ($p<0.05$) as they are influenced by different factors (concentrations of H^+ and salinity, respectively). The pH also had no association with the growth, nutrition and biomass production parameters of cocoa, except for its negative influence on leaf expansion/Leaf Area (LA) at 6 weeks of growth. At the initial growth stage, alkaline soil condition due to low H^+ and high Ca^{2+} concentrations of the irrigation water forms might have caused the deficiency of some nutrients; thus affecting leaf expansion negatively. The magnitude of vegetative growth in crops is closely associated with the supply of nutrients, particularly N (Akintunde, 1992; Akintoye *et al*., 1997; Akintunde *et al*., 2000) and for a young, unclosed canopy, the relation between LA and N is nearly linear (Yin *et al*., 2003).

Table 8 indicates that electrical conductivity (salinity condition) of irrigation water changes linearly with the amounts of moisture and biomass in shoots and roots of cacao seedlings. Nevertheless, the correlation with

Table 8: Percent nitrogen and phosphorus contents in the tissue of leaves of cacao seedlings irrigated with water from different sources

Irrigation water sources	P in leaf tissue (%)		N in leaf tissue (%)	
	F_3 Amazon	Amelonado	F_3 Amazon	Amelonado
Stream	0.38	0.36	4.27	4.41
Borehole	0.37	0.35	4.97	4.48
River	0.34	0.36	4.41	4.34
Well	0.34	0.36	4.27	4.48
Rain	0.31	0.43	4.20	4.97
Sea	0.35	0.36	4.20	4.22
LSD (5%)	0.02	0.03	0.27	0.24
	P uptake (mg pot^{-1})		N uptake (mg pot^{-1})	
	F_3 Amazon	Amelonado	F_3 Amazon	Amelonado
Stream	16.34	12.24	183.61	149.94
Borehole	10.73	15.40	144.13	197.12
River	13.60	20.16	176.40	243.04
Well	14.96	12.60	187.88	156.80
Rain	13.02	20.64	176.40	238.56
Sea	1.75	2.52	21.00	29.54
LSD (5%)	5.51	6.99	67.51	82.89

Table 9: Correlation coefficients relating pH and Electrical Conductivity (EC) of irrigation water forms, biomass yield components as well as nitrogen and phosphorus nutrition parameters after twenty-one weeks of cacao seedlings growth

	H_2O-sources												
	pH	EC	Fresh root	Dry root	Fresh shoot	Dry shoot	Root-shoot ratio	Shoot moisture (%)	Root moisture (%)	P (%)	N (%)	P-uptake	N-uptake
H_2O^{-}] pH	1	0.43	-0.43	-0.47	-0.33	-0.34	-0.02	0.27	0.43	-0.22	-0.32	-0.51	-0.51
sources] EC		1	-0.99**	-0.89**	-0.89**	-0.91**	0.48	0.58*	0.65*	-0.07	-0.39	-0.86**	-0.90
Fresh root			1	0.92**	0.88**	0.90**	-0.44	-0.64*	-0.68**	0.06	0.35	0.88**	0.92**
Dry root				1	0.86**	0.91**	-0.25	-0.69**	-0.91**	0.12	0.23	0.98**	0.99**
Fresh shoot					1	0.99**	-0.68**	-0.36	-0.70**	0.13	0.38	0.84**	0.87**
Dry shoot						1	-0.61*	-0.49	-0.76**	0.11	0.35	0.88**	0.91**
Root-shoot ratio							1	-0.18	-0.00	-0.03	-0.43	-0.24	-0.29
Shoot moisture (%)								1	0.61*	0.13	-0.04	-0.63*	0.67**
Root moisture (%)									1	-0.18	-0.09	-0.90**	0.89**
P (%)										1	0.68**	0.34	0.24
N (%)											1	0.37	0.37
P- uptake												1	0.99**
N- uptake													1

n = 12, *, ** r-values significant at $p<0.05$ and $p<0.01$, respectively

percentage moisture was positive while it was negative with respect to biomass. Thus, the higher the EC, the more the percentage moisture in shoots and roots but the lower the biomass produced in these plant's organs. This seems to be an adaptation mechanism for the plant to maintain the osmotic pressure in its cell sap or tissues. Mahmood *et al.* (2001), Qureshi and Barrett-Lennard (1998) referred to the accumulation of salt in the organs of tree plantations using saline water and noted that the salt concentrations may eventually accumulate to high levels, which adversely affect tree growth, health and survival. It seems obvious, however, that this may only be the case under steady-state moisture conditions in which no leaching of the root zone (due to flooding, irrigation or seasonal rainfall) takes place. In this study, the dilution effect arising from increased amount of moisture when EC increases, is further portrayed by the close relationship between percentage moisture in shoots or roots and shoots or root biomass (Table 8).

EC was also well correlated with crop uptake of both N and P but not with their contents in plant tissue (Tables 5 and 8). Nutrient contents may fluctuate greatly with variation in percentage moisture contents, particularly with variable EC; hence, the lack of association between EC and nutrient contents. On the contrary, uptakes of the nutrients are tied with Dry Matter (DM) that is less prone to variability. This fact is buttressed by the lack of significant correlation between the nutrient contents in plant tissue and the uptake values while the close association between P% and N% is a vivid illustration of nutrient synergism.

Despite the known influence of P on root growth (Ojo, 2000), percentage P neither correlated with root biomass nor with the root/shoot ratio (Table 9) while the correlations of these seedling growth parameters with P-uptake were very close ($r \geq 0.88$). P uptake also correlated with some of the growth parameters, particularly stem girth and plant height, at 6 weeks but not at 21 weeks. This is not surprising as there was no relationship between the values of each of these parameters at both stages of growth. P uptake did not correlate with leaf canopy spread production at 6 and 21 weeks. Like in the case of P, N% was also not associated with most of the growth parameters, which correlated well with P uptake.

It is evident from this study that except for seawater, irrigating cacao seedlings with water from the other sources tested would not substantially affect the associated nutrition and performance parameters.

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