THE EFFECTS OF BALLAST WATER FROM BRACKISH WATER AND OBSERVED TEMPERATURE VARIATION ON THE GROWTH AND DEVELOPMENT OF RED PEPPER (C*APSICUM FRUTESCENS* L.).

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ABSTRACT
Ballast water is mostly sea water placed on hold in ships to ensure stability while on board. Lack of enforced regulations on ballast exchange resulted in its indiscriminate discharge without considering its consequences on plants and our environment. The effects of ballast water (25, 50, 75 and 100% concentrations) and increased temperature (observed in the screen house) on the growth and development of *Capsicum frutescens* were studied. The experiment was carried out in a randomized complete block design at the experimental screen house of Plant Biology Biotechnology, University of Benin, for 15 weeks. The results (expressed in ppm or mg/l) showed that pH, Na, K, Ca, Mg, Fe, Zn, Mn, Cu, electrical conductivity (1067µg/cm), TDS (0.41 ppm), BOD (2.6 ppm), TSS (0.38 ppm) and chlorides (561.22 ppm) were within the accepted standards of WHO and NESREA. They showed that ballast water would be suitable for watering plants. The water enhanced the growth of the test plant. Significant difference was not observed at 5% level ($P < 0.05$) in the parameters tested for *C. frutescens*. Temperature increase was observed as the factor because the control plants cultivated outside the screen house flowered and fruited. Since high electrical conductivity and alkalinity observed in the ballast is an indication of toxicity, further study is therefore recommended to access the metal uptake and cytotoxicity of the test plant to know if the plant treated with ballast water would be suitable for consumption.

Key words: Ballast water, C*apsicum frutescens* L., concentrations, development, growth, increased temperature.

INTRODUCTION
Ballast water is often sea water taken on hold in a ship while on board to maintain stability while moving from one shoreline to another within the same /or different country, and discharged before loading or unloading. It is one of the primary vectors responsible for the global transport of vegetative and resting stages of aquatic microorganisms as well as potentially pathogenic bacteria. Control of discharge of ballast water is thus an international issue, handled by the International Maritime Organisation (IMO). Internationally, there has been slow but steady progress towards international legally binding control on ballast water (Ruiz et al., 2000; Olorunfemi et al., 2012). The United Nations General Assembly in the year 2000 adopted the millennium Development Goals (MDGs). The MDGs most directly related to the safe use and discharge of wastewater is to ensure environmental sustainability. In order to maximize the health and environmental benefits associated with the use and discharge of wastewater, several legislations and guidelines have been developed, both at international and national level. The World Health Organization (WHO) Guidelines for the reuse of effluents were developed in 1973, with revised editions in 1989 and 2006 (WHO, 2006). In Nigeria, ballast water is indiscriminately discharged without regards to its impact on our health, plants and environment (Olorunfemi et al., 2012).

Global temperature has increased by 0.3–0.6°C since the late 19th century and by 0.2–0.3°C over the last 40 years. In the last 140 years, the 1990s was the warmest period (Jones and Briffa, 1992).It was reported that photosynthetic rate decreases with high temperature (32 ^{0}C) at both pre-flowering and flowering stages in tomato genotypes. Number of fruits per plant, individual fruit weight and fruit yield significantly decreased at 32^{0}C at pre-flowering and flowering stages, but the decrease was more evident at flowering stage than at pre-flowering stage. The synthesis of chlorophyll content was blocked because of high temperature (Islam, 2011).

Capsicum frutescens also known as red pepper originates from South and Central America. It belongs to the family of Solanaceae of which tomatoes, potatoes and eggplant belong. It is a short-lived evergreen shrub usually 1 to 1.5 m in height and 1 to 3 cm in basal stem diameter and grows on soils of all textures in a wide range of fertilities. Moist, well-drained conditions and loose structure are most suitable for its rapid growth. Soil pH of 4.3 to 9.7 is tolerated. After about 3 months of growth, *C. frutescens* flowers and fruits continuously as long as it lives. Under continually favorable conditions, *C. frutescens* lives about 2 years (Ikeh et al., 2012; Bosland and Votava, 2000).

Previous studies showed that ballast water inhibited the germination of *Zea mays* L., *Arachis hypogeal* L., and *Abelmoschus esculentus* L. it also reduced the yield of *Zea mays* and affected the root growth of *Allium cepa*. The objective of this study is to determine the effects of ballast water and temperature variations on the morpho-physiological parameters of *C. frutescens*. *C. frutescens* is a useful vegetable crop that needs to be protected for its numerous benefits.

MATERIALS AND METHODS

Ballast water collection

The ballast water used for the study was collected from M/V Arosa. M/V Arosa is a multipurpose vessel carrying dry cargo; its gross tonnage is 12578; IMO number, 9229879. It was built in 2002. It sails under the flag· of Malta, and was registered in Switzerland (CH). It has 155m length, 22m beam and 2000lt deadweight. The owner of the vessel is Massatlanticsa. Its ballast capacity is 6083.4CBN. The vessel came from Liberia and berthed at the jetty of Koko Port (located in Warri North Local Government Headquarters in the town of Koko) on the 23rd of November, 2012.

Physico-chemistry

The physico-chemical parameters of the ballast water determined were pH, Electrical Conductivity (E/C), Total Dissolved Solid (TDS), Salinity, Biochemical Oxygen Demand (BOD), Total Soluble Solid (TSS), total hardness, total solid (TS), Turbidity, Phosphates, Nitrates, Acidity, Alkalinity, SO_4^{2-}, Chlorides (Cl^{-}), Oil and Grease, Heavy Metals (Lead, Chromium, Manganese, Nickel, Zinc, Iron, Copper, Cadmium and Cobalt) and light metals (Sodium, Potassium, Calcium, Aluminium and Magnesium). They were analyzed using standard procedures (Ademoroti, 1996 cited in Onuegbu et al., 2013). The samples were digested using Atomic Absorption Spectrophotometer Buck Scientific AAS 205 model (Karunyal et al. 1994; APHA, 1995). The results were compared with WHO and NESREA limits (Onuegbu et al., 2013).

Ballast water preparation and seed collection

The experimental design used for this study was randomized complete block design (RCBD) with five treatments and five replicates. Seed collection and soil preparation were done using the modified methods of Karunyal et al. (1994) cited in Olorunfemi et al. (2008).

Measurement of morphological and physiological parameters

The morphological and physiological parameters examined are; Plant Height, Stem Girth, Chlorophyll Content Determination (vwioko, 2008) and Measurement of Plant Biomass (fresh and dry weight) (Khan et al., 2011).

Statistical analyses

It was done using SPSS programme (version 16). Significant differences in measured parameters were compared by one-way ANOVA and Ducan´s Multiple Range Test at 5% probability level (Singh and Agrawal, 2010).

DISCUSSION

The growth of *Capsicum frutescens* was not negatively affected by the varying concentrations of the ballast water. The ballast water used for the study had a pH value of 6.3 which was within the permissible value of WHO (2011) and NESREA (). Nitrate (0.21) was below the permissible value. The mean value of phosphate is 420 mg/l and is higher than the standard set by WHO and NESREA limits (Onuegbu et al., 2013). Olorunfemi et al. (2012) stated that a high concentration of phosphate like this is an indication that the ballast water is polluted and this condition can result in entrophication.

Table 1 shows the metal content of sodium (Na), Potassium (K), Calcium (Ca) and Magnesium (Mg) to be 20.50, 11.7, 1.6 and 0.73 respectively. The Na and K values were below the set limits of WHO. The presence of metals such as Na, K, Ca, Mg and Fe (Table1) in the ballast water within the set limit of WHO and NESREA limits (Onuegbu et al., 2013)] might have enhanced the growth of *C. frutescens*. This is in line with Kolay (2000) who stated that macro elements are essential for plants' growth and development. The study also indicates that chloride concentration was 561.22, which was higher than the acceptable limits of WHO but was within the standard of NESREA for irrigation. Heavy metals such as Zn (0.04), Mn (0.01) and Cu (0.01) where present below the set limit. Chromium (Cr), Lead (Pb), Cadmium (Cd), Cobalt (Co) and Nickel (Ni) were not present (Table 1). High E.C is an indication of the level of dissolved solids in solution. On a general note, waters with electrical conductivity (E.C) values above 1000µs/cm but below 40,000 indicate that the ballast water is a brackish water (Olorunfemi et al., 2012) .The value of electrical conductivity of the ballast was 1067(µs/cm). This value was within the set standard of WHO. The alkalinity of the ballast water was 228.0(mg/l). A higher alkalinity value such as this one as stated by Akpofure (2009) could indicate the presence of unionized ammonia, which is toxic.

The study also shows from the soil

Table 1. Ballast water physico-chemical parameters.

Parameter	Result	WHO **	NESREA **
pH	6.3	6.0-9.2	6.5-8.5
Na (mg/l)	20.50	20-200	<20
K (mg/l)	11.7	200	-
Ca (mg/l)	1.6	<100	-
Mg (mg/l)	0.73	-	-
Fe (mg/l)	0.13	1.0	0.5
Zn (mg/l)	0.04	3.0-15	0.2
Mn (mg/l)	0.01	0.4	40.0
Ni (mg/l)	-	0.01	0.01
Cu (mg/l)	0.01	1.0	0.01
E/C (µg/cm)	1067	900-1400	-
TDS (ppm)	0.41	1200	-
Salinity (%)	0.01	-	-
BOD (ppm)	2.6	15	6.0-30
TSS (ppm)	0.38	<30	30
Turbidity(NTU)	10.5	5.0	10
NO_3^- (ppm)	0.21	10-50	10-20
SO_4^{2-} (ppm)	-	250-500	500
PO_4^{2-} (ppm)	420.0	3.5	2.0
Cr (mg/l)	-	0.005-0.05	0.5
Pb (mg/l)	-	0.015-0.01	40.0
Cd (mg/l)	-	0.003	0.001
Oil and Grease(ppm)	-	<0.01	0.1
TS (ppm)	0.79	500	500
Acidity (ppm)	25.2	-	-
Alkalinity (ppm)	228.0	-	-
T/Hardness (ppm)	0.04	0-75	150
Cl^- (ppm)	561.22	100-250	350-600

** ⟶ (WHO, 2011; Okieimen et al., 2012; Onuegbu et al., 2013; Umudi, 2011).

characterization that it was a well drained sandy-loamy soil, with a pH range of 8.05 – 8.93 (Table 2). The concentration of Na, K, Ca and Mg is an indication that the soil was enhanced with Na (1046), K (1353), Ca (1317.83) and Mg (935.38). Aluminium (Al), Iron (Fe), Zinc (Zn) and Manganese (Mn) are also present in the soil. Metal contents of Al, Fe, Zn and Mn are 0.31, 261.54, 16.54 and 3.77 (ppm) concentrations respectively. Chlorides (Cl^-), sulphates (SO_4^{2-}), Phosphates (PO_4^{2-}), Ammonium ion (NH_4^+), Nitrates (NO_3^-) and organic carbon (%) are also present. The concentrations of Cl^-, SO_4^{2-}, PO_4^{2-}, NH_4^+ and NO_3^- are 8.10, 5.88, 69.50, 0.04 and 110.90 respectively.

Table 2. Soil physico-chemical parameters.

Parameter	Control (0%)	Pre-treatment	Post-treatment			
			25%	50%	75%	100%
Na (mg/l)	1150	1146	1235	1282	1157	930
K (mg/l)	1004	1353	1286.92	1424	1308	1175
Ca (mg/l)	1462.31	1317.83	1164.62	1390	1355.39	1450
Mg (mg/l)	1260.76	935.38	1299.23	1160	1275.38	1311.54
Al (mg/l)	-	0.31	0.85	0.54	1.46	-
Fe (mg/l)	484.62	261.54	430.77	484.62	485	630.77
Zn (mg/l)	17.46	16.54	17.62	16.62	17.23	18.08
Mn (mg/l)	10.62	3.77	8.69	7.92	10.23	11.69
pH	8.11	8.77	8.05	8.65	8.39	8.93
Cl^-(mg/kg)	13.92	8.10	15.27	24.85	22.51	32.02
SO_4^{2-} (ppm)	8.39	5.88	6.55	7.90	8.59	9.16
PO_4^{2-} (ppm)	175.10	69.50	105.10	70.90	55.60	195.20
$NH4^+$ (ppm)	0.07	0.04	0.10	0.11	0.03	0.13
NO_3^- (ppm)	111.70	110.90	100.50	131.10	135.30	241.50
%Org. Carbon	3.52	3.00	3.39	4.22	3.82	5.11
Cr (mg/l)	8.54	8.08	16.46	10.54	12.23	8.77
Pb (mg/l)	-	0.08	0.54	0.15	0.46	-
Cu (mg/l)	0.69	0.46	1.38	0.23	0.77	1.00
Cd (mg/l)	-	-	-	-	-	-
Co (mg/l)	-	0.77	0.85	0.62	0.38	-

In comparison with the control, Cl^-, SO_4^{2}, NO_3^- and organic carbon contents are much higher except for PO_4^{2-} and NH_4^+ where the control was higher. Table 2 also shows that heavy metals such as Cr, Pb, Cu and Co were present at concentrations of 12.23, 0.46, 0.77 and 0.38., and were higher than the control (Table 2).

The pH of the 100% ballast water treated soil (8.93) revealed that it is most of the treatments were alkalinic. Metal contents of Na, K, Ca, Mg, Fe, Zn and Mn had 930, 1175, 1450, 1311.54, 630.77, 18.08 and 11.69 (ppm) concentrations, and were higher than the control except Na and Ca. Aluminum was not present. Cl^-, SO_4^{2-}, PO_4^{2-}, NH_4^+, NO_3^- and organic carbon were also higher than the control. The heavy metals Pb, Cd and Co were not detected but Cr and Cu were present at 8.77 and 1.00 (ppm), and are also much higher than the control (Table 2).

Figure 1 shows the effect of ballast water and temperature studied on plant height of *Capsicum frutescens* with different concentrations of ballast water for 14 weeks. Statistical analysis indicates that no significant difference was observed at 2 - 8 weeks after planting of *C. frutescens* ($P < 0.05$) except at 10 – 14 weeks. For the control treatment the range of increase in plant height was 5.06 ± 0.42 – 32.9 ± 5.01, while for the treatments the increase was 4.30 ± 0.45 - 41.4 ± 5.22.

Stem girth of *C. frutescens* ranges from 0.18 (week 4) to 0.33 (week 14) (Figure 2). Significant differences were not observed in all the treatments except at 10 to 14 weeks after planting. In comparison with the control, all other treatments increased in girth which indicates that ballast water

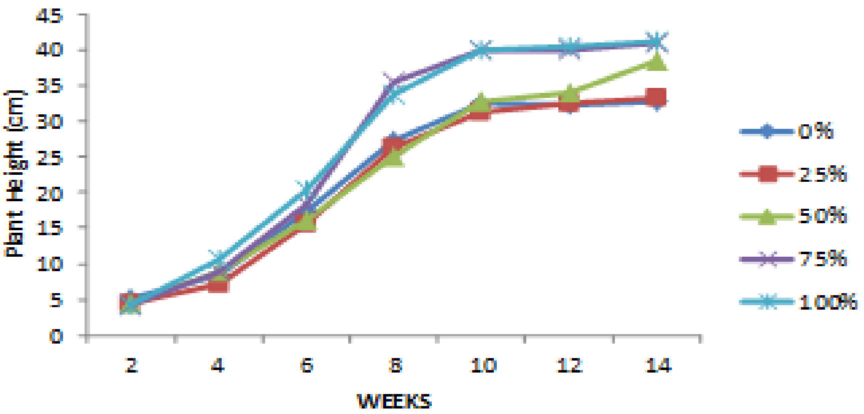

Figure 1. Effect of temperature and ballast water on plant height (cm) of *Capsicum frutescens* L.

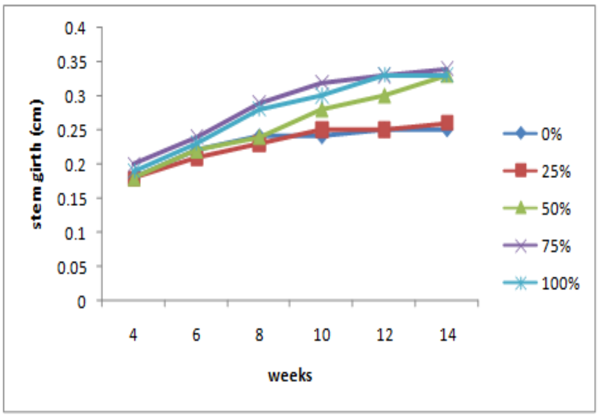

Figure 2. Effect of ballast water and temperature variations on stem girth of *Capsicum frutescens* (cm).

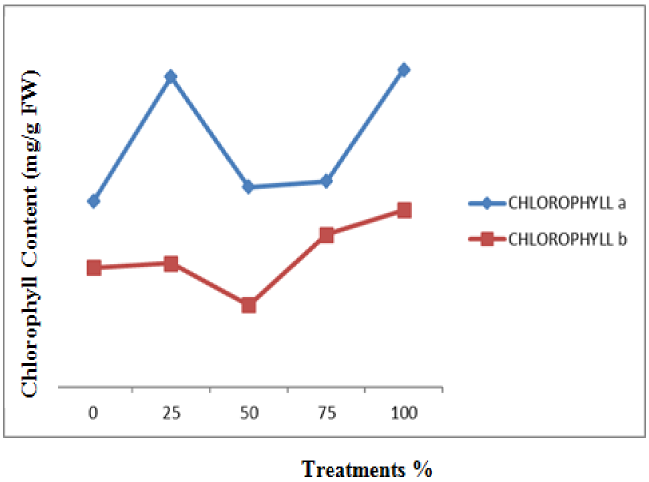

Figure 3. Effect of temperature and ballast water on chlorophyll content on *Capsicum frutescens.*

enhanced the growth of the test plant. Temperature had no negative impact on the stem girth of *C. frutescens*.

From the study, it was observed that the value of chlorophyll *a* content of *C. frutescens* (Mg/gFW) range from 1.29 ± 0.33 to 2.21 ± 0.09, while that of chlorophyll *b* (Mg/gFW) was 0.57 ± 0.12 (50%) to 1.23 ± 0.51 (100%). There was no significant difference observed ($p < 0.05$) among the mean values of chlorophyll *a* and *b* (figure 3). The physico-chemical analysis of the ballast water showed that magnesium has 0.73 ppm; potassium, 11.7 ppm while the phosphates (PO_4^{2-}) was 420 ppm. The soil is high in Phosphates, Potassium, Magnesium and Calcium. The result is in agreement with Kolay (2000) who stated that Magnesium and Nitrogen are essen-tial compo-nents of the chlorophyll content. Temperature increase did not significantly affect the chlorophyll

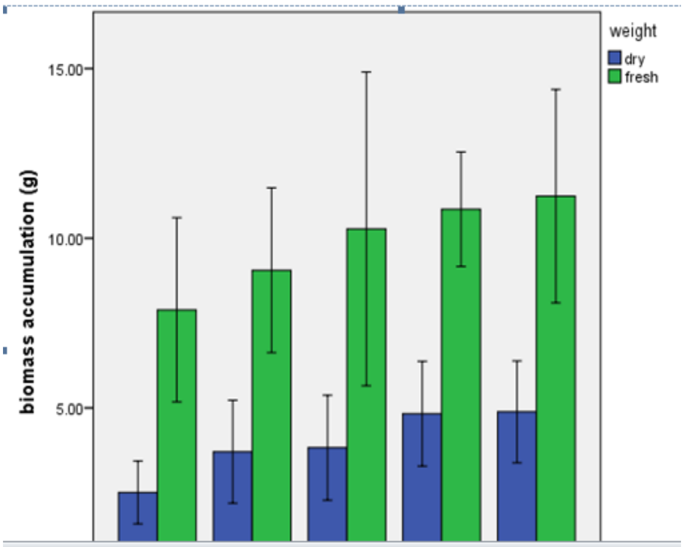

Figure 4. Biomass determination of *Capsicum frutescens* (g) at 15^{th} week.

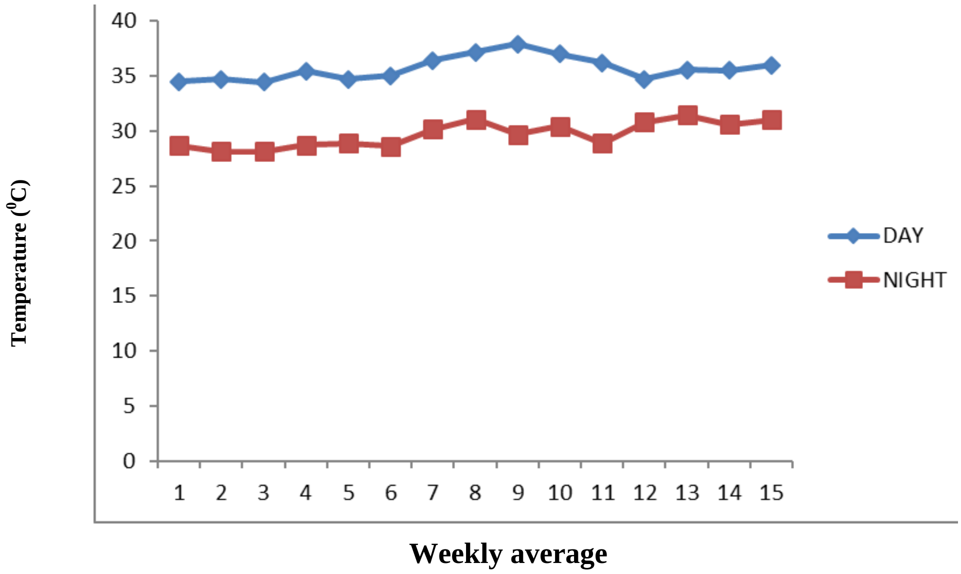

Figure 5. The average weekly temperature measurement of the experimental screen house from the planting date.

chlorophyll content of the test plant.

Figure 4 shows that fresh weight biomass (g) of *C. frutescens* varied from 7.90 to 11.24 ($P < 0.05$). The oven dry weight (g) of *C. frutescens* ranges from 2.51 to 4.88 (Figure 4).

The present study (Figure 5) also shows the effects of temperature on the growth and development of *C. frutescens*. On the weekly average, the highest temperature recorded lies with week 7 – 10. From week 1 – 6, the test plants were able to adapt or acclimatize to the temperature variations and the plants grew well in length and also increased in girth considerably (Figure 3). Though it was observed that *C. frutescens* increased in girth, the plant, except 100% treatment did not flower and the flowers of the 100% treatments did not develop into fruit as they fell off after 2 days of observation. This is due to some unfavorable conditions of which an increase in temperature was the major factor.

As stated above, the day temperature of the screen house ranged from 34.43 to 37.93 (^{0}C) while the night temperature ranged from 28.14 to 31.43. The plant did not flower or fruit but it gradually depreciated until more leaf fall was experienced and finally the plant started to die starting with the wilting of the shoot tips. The experiment was finally terminated at 15 WAP when the test plant did not show any further sign of development particularly for flowering and fruiting. To further buttress the effect of temperature on the growth and development of *C. frutescens*, the experiment conducted outside the screen house flowered and fruited. The flowering was observed at 9 weeks and four days after planting.

Conclusion

Ballast water enhanced the growth and development of the test plant; though, flowering and fruiting was a limitation attributed to high temperature in the screen house.

The physico-chemical characterization of the examined ballast water shows that Zn, Cu, Al, Ni and Mn, Pb, Cd and Co, and SO_4^{2-}, CO_3^-, oil and grease, BOD, TSS, TDS, E/C, TS, Total hardness, K, Ca, Fe, Mg, and Na within the accepted standard of NESREA and WHO indicate that the ballast water might have been treated and would be suitable for irrigating plants. Hence, ballast water like this would be suitable for irrigation as it enhanced the growth of *Capsicum frutescens* L. Since high electrical conductivity and high alkalinity observed in the ballast showed a level of toxicity, further study would be conducted to examine the metal uptake of the plant and the cytotoxicity effects on the plant.

ACKNOWLEDGEMENTS

This research was funded by Mr. S. O. and

Mrs F. E. Egboduku. The Department of Plant Biology and Biotechnology, Faculty of Life Sciences, University of Benin, Benin City, Nigeria also supported this work.

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