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Response of Maize (*Zea mays* L.) Genotypes to Liquid Effluents from a Non-alcoholic Beverage Company in Ibadan, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study was conducted to investigate the effect of liquid effluents discharged from a non-alcoholic beverage company on the growth of maize genotypes.
Study Design: The screenhouse experiment was laid out in complete randomised design.
Place and Duration of Study: The experiment was conducted at the nursery farm of the Department of Botany, University of Ibadan, Nigeria, between January and February and repeated between March and April, 2018.
Materials and Methods: Maize genotypes; TZM – 1439, TZM – 29, TZM – 1288 and TZM - 1165 were obtained from maize germplasm in IITA Ibadan while the liquid effluent was collected from a bottling company in Ibadan and diluted with sterile distilled water into four different concentrations (0, 80, 90 and 100%). The varying concentration levels were evaluated on each maize genotype. Effluent was applied in the soil of the respective treatment at 200ml /pot/ day starting from the 10th day after planting. Data gathered on plants' growth characters were subjected to ANOVA $\alpha_{0.05.}$
Results: Maize cultivars treated with effluents concentrations, especially at 100% level significantly ($p < 0.05$) resulted in increased plant height (31.17 and 28.67 cm), stem length (7.81 and 7.53 cm),

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leaf length (22.18 and 20.63 cm) and leaf number (3.72, 3.61%) compare to the control respectively. Among the maize genotypes evaluated, TZM–1439, TZM-29 and TZM–1288 showed the most significant ($p<0.05$) effect on all the growth characters measured. No significant correlation exists between the effluent concentrations and genotypes with the growth characters, while the eigen proportion ranged from Prin 1 (67.10%) to Prin 5 (2.22%).

Conclusion: The effluent from non-alcoholic beverage company's treated maize plants recorded better growth performances at higher concentrations compare to the control experiment and could be further investigated for use in irrigation farming towards sustainability in agriculture.

Keywords: Maize genotypes; beverage company; effluents concentrations; eigen proportion.

1. INTRODUCTION

Maize is one of the most important cereals which is a major source of nutrient for humans, feed and fodder for livestock, while maize silage is one of the most valuable forages for ruminants [1,2]. Maize is also used for different purposes; it serves as a basic raw material for the production of starch, oil, protein, alcoholic beverages, food sweeteners and, more recently, fuel [3,4].

Industrialization is the process of transformational change of the human socially and economically, from agrarian into an industrial environment. It also involves vast economic and social changes such as tendency to urbanization, a growing body of wage earners and increased technical and advanced education [5]. However, rapid industrial development and the world global growth have led to the recognition and increasing understanding of interrelationship between pollution, public health and environment [6]. Industries vary in size, scope, level of technology, products, characteristics and complexity of water discharged. Majority of industries produce large amounts of effluents. These effluents are released into the environment where they come in contact with various human activities such as farming [6,7].

Depending on the environmental laws governing a locality and extent of its enforcement, the effluents are treated before their discharge to environment. While this law has not being strictly adhered unto by many industries, yet the treated effluent still contains heavy chemicals which accumulate in the ecosystem into quantities that pose serious threat [8]. Industrial wastewaters range from high biochemical oxygen demand (BOD) from biodegradable wastes such as those from human sewage, pulp and paper industries, slaughter houses, tanneries, chemical industry, to those from plating shops and textile mills which may be toxic and require on-site physico-chemical pre-treatment [9]. More so, the heavy metals present in the industrial waste water such as lead, cadmium, chromim, nickel, zinc, and arsenic are the most toxic and perilous materials among the other toxic materials from the chemical and allied industries [10]. Thus, the continuous disposal of industrial effluents on land often leads to contamination of both agricultural soil and ground water by these heavy metals [11]. If such heavy metal polluted soil is used for crop cultivation then the heavy metals deposited in soil enter into the food chain and at higher concentration create severe human health problems [12]. Since plants are the initial recipients of these pollutants in the food chain, there is need to study the possible effect of industrial effluent on plants. This study, therefore, investigated the effect of different levels of liquid effluents on the growth of different genotypes of maize.

2. MATERIAL AND METHODS

2.1 Study Place and Plant Materials

Experiments were carried out in the screenhouse between January and February and repeated between March and April, 2018, at the nursery farm (Longitude 7.17°N and Latitude 3.90°E) of the Department of Botany, University of Ibadan, Nigeria. Four maize genotypes (TZM – 1439, TZM – 29, TZM – 1288 and TZM – 1165) were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, while the industrial effluent was collected from a bottling company in Ibadan, Nigeria.

2.2 Experimental Design and Treatments

The experiment was laid out in complete randomized design with four replications. The effluent was diluted with distilled water into four concentrations (0, 80, 90 and 100%).

2.3 Crop Conduction and Effluent Management

The maize genotypes were planted in sterilised soil inside the polythene bags. The polythene bags were spaced at a distance of 30 cm. Three seeds each of maize were planted into each polythene bag and later thinned to one. The crop was grown under normal condition for a period of nine days after planting, watered at 200 ml per pot per day. At ten days after planting the treatment with effluent concentrations was started. Maize plants in the control treatment (0% effluent) continued to be irrigated with sterile distilled water at 200 ml per pot per day.

2.4 Variables Evaluated

At three-day intervals, between 10 and 25 day after planting, the following parameters were determined: plant height (cm), leaf length (cm), leaf number and leaf width (cm).

2.5 Statistical Analysis

Data were subjected to analysis of variance (ANOVA) by F test using SAS 9.1 statistical analysis software [13] and means were separated by Duncan Multiple Range System. The Principal Component Axis (PCA) was generated using PAST 03 statistical software.

3. RESULTS

The effect of interactions of effluent at varying concentrations with maize genotypes and period of observation of the experiment showed that maize genotypes and period of experiment had highly significant ($p < 0.001$) effect on the growth characters measured; plant height, stem length, leaf length, leaf number and leaf width. The effluent concentrations only showed significance with plant height at $p < 0.01$, also with leaf length and leaf number at $p < 0.05$. The first order of interactions involving genotype (G), effluent concentration (C), period (P) and replicates (R) were significant ($p<0.001$) on all the growth characters except C x P that showed significance ($p < 0.01$) only with leaf length and P x R with stem length at $p<0.05$ (Table 1).

Maize genotype TZM – 1439, TZM -29 and TZM – 1288 showed the most significant ($p < 0.05$) growth in the plant height, leaf length and leaf width. TZM - 29 recorded the most significance with stem length and TZM – 1439 with number of number (Table 2).

The result in Fig. 1 showed the dendogram expressing the relationship among the genotypes after treatment with the effluents. TZM-1165 was observed in the first cluster while TZM – 1439, TZM -29 and TZM – 1288 were in the second cluster. However, TZM -29 and TZM – 1288 were further sub-grouped.

The most significant growths in the plant height, stem length, leaf length and leaf width were recorded in the plants treated with 100% effluent concentration level. Concentrations at 80 and 90% also significantly increased the plant height, number of leaves and leaf width of the plants when compared to the control (0%). However, the similar result was obtained with the leaf width across the concentration levels. Across all the characters, the growths of plants increased significantly with the increase–in the days after planting (Table 3).

Table 1. Mean square effects of effluents and different genotypes on the growth characters of maize

Sources of variation	DF	Plant height	Stem length	Leaf length	Leaf number	Leaf width
Effluents concentration (C)	3	125.20^{**}	6.24^{ns}	48.25^{*}	1.27^{*}	0.02^{ns}
Genotype (G)	3	3084.60^{***}	246.20^{***}	4033.56^{***}	27.67^{***}	1.58^{***}
Period (P)	5	19195.57^{***}	882.00^{***}	9657.19^{***}	89.79^{***}	1.27^{***}
Replicates (R)	3	324.34^{***}	25.60^{***}	104.18^{**}	1.26^{**}	0.29^{***}
G x C	9	317.34^{***}	19.78^{***}	127.83^{***}	2.75^{***}	0.29^{***}
C x P	15	23.22^{ns}	19.57^{ns}	37.48^{**}	0.33^{ns}	0.03^{ns}
G x P	15	173.01^{***}	16.50^{***}	855.01^{***}	0.86^{**}	0.18^{***}
G x C x P	45	31.93^{ns}	1.74^{ns}	26.83^{*}	0.35^{ns}	0.05^{ns}
Error	180	22.61	2.5	17.2	0.35	0.04
Corrected total	479					

*DF – Degrees of freedom, *Significant at p < 0.05, **Significant at p < 0.01, *** Significant at p < 0.001*

Table 2. Genotypic effect on growth characters of maize

Maize genotypes	Plant height (cm)	Stem length (cm)	Leaf length (cm)	Number of leaves (cm)	Leaf width (cm)
TZM – 1439	32.48a	7.91b	24.57a	4.16a	1.55a
TZM -29	32.61a	8.46a	24.15a	3.99b	1.51a
TZM – 1288	32.56a	8.30ab	24.26a	3.74c	1.55a
TZM – 1165	22.41b	5.40c	12.74b	3.07d	1.31b

Means with the same letter in the same column are not significantly different at p>0.05 using Duncan's multiple range test

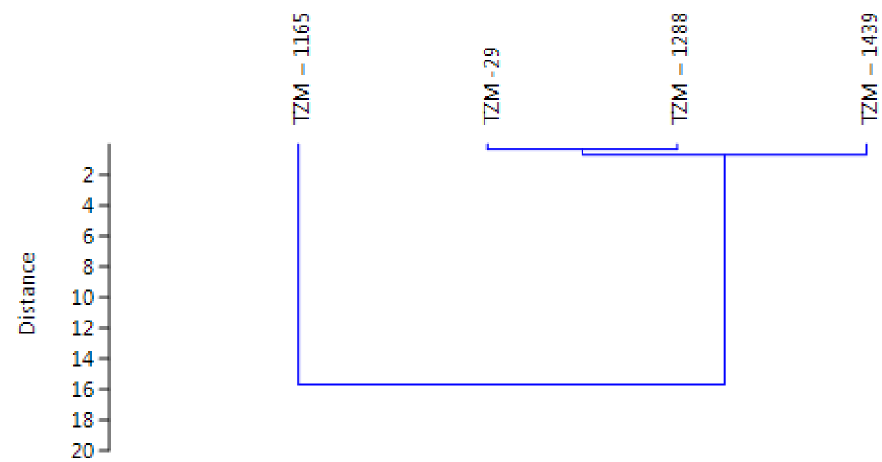

Fig. 1. Dendogram showing the relationship in response of maize genotypes to the liquid effluent

Table 3. Effect of the effluents concentration on the growth characters of maize

Sources of variation	Variables	Plant height (cm)	Stem length (cm)	Leaf length (cm)	Leaf number (cm)	Leaf width (cm)
Effluent Concentration (%)	**0 (Control)**	28.67b	7.53ab	20.63b	3.61b	1.47a
	80	30.18a	7.47ab	21.50ab	3.78a	1.49a
	90	30.03a	7.26b	21.41ab	3.85a	1.49a
	100	31.17a	7.81a	22.18a	3.72ab	1.47a
Period (Days after planting)	**10**	9.24f	2.98f	6.26e	2.31f	1.33e
	13	14.84e	4.34e	10.50d	2.81e	1.39de
	16	27.91d	7.26d	20.65c	3.61d	1.44cd
	19	37.35c	8.88c	28.47b	3.99c	1.47c
	22	43.42b	10.21b	29.48b	4.59b	1.54b
	25	47.33a	11.43a	32.21a	5.13a	1.69a

Means with the same letter in the same column are not significantly different at p > 0.05 using Duncan's multiple range test

The result in Table 4 showed correlation among the genotype, effluents and the growth characters of maize. The stem length, leaf length, leaf number, leaf width and period correlated positively with the plant height with r = 0.93, 0.90, 0.89, 0.63 and 0.84 respectively with $p < 0.01$. Leaf length, leaf number, leaf width and period correlated positively with stem length with r = 0.81, 0.84, 0.63 and 0.77 respectively. Leaf length is positively associated with leaf number, period and leaf width at r = 0.78, 0.69 and 0.55 respectively. The leaf width and period are positively related to leaf number with r = 0.72 and 0.75.

Table 4. Correlation coefficient among genotype, effluent concentration and growth characters of maize

Correlation	Plant height (cm)	Stem girth (cm)	Leaf length (cm)	Leaf number (cm)	Leaf width (cm)	Genotype (cm)	Conc (%)	Period	Replicates
Plant height									
Stem girth	0.93**								
Leaf length	0.90**	0.81**							
Leaf number	0.89**	0.84**	0.78**						
Leaf width	0.63**	0.63**	0.55*	0.72**					
Genotype	-0.20	-0.22	-0.29	-0.31	-0.27				
Conc	0.02	-0.02	0.02	0.06	0.04	0.00			
Period	0.84**	0.77**	0.69**	0.75**	0.38	0.00	0.00		
Replicates	0.09	0.10	0.06	0.08	0.15	0.00	0.00	0.00	

** Significant at $p < 0.05$, **significant at $p < 0.01$, Conc = Effluent concentration*

Table 5. Principal component analysis (PCA) of growth characters of maize treated with liquid effluent

PCA	Prin 1	Prin 2	Prin 3	Prin 4	Prin 5
Plant height	0.51	-0.26	-0.01	-0.04	-0.82
Stem length	0.46	-0.13	-0.82	0.04	0.33
Leaf length	0.42	-0.60	0.51	0.14	0.44
Leaf number	0.44	0.21	0.21	-0.74	0.17
Leaf width	0.41	0.61	0.17	0.66	0.03
Eigen value	3.36	0.8	0.42	0.32	0.11
Proportion (%)	67.10	15.96	8.32	6.41	2.22

The result in Table 5 shows the principal component analysis of maize genotypes treated with liquid effluents. Prin 1 accounted for 67.10% of the total variation, while Prin 2, Prin 3, Prin 4, accounted for 15.96, 8.32, 6.41 and 2.22% of the total variation respectively. Prin 1 showed that the stem length (0.46), leaf length (0.42), leaf number (0.44) and leaf width (0.41) were closely related to one another compared to the plant height (0.51). The plant height greatly contributed to Prin 1 while Prin 2 showed that plant height (-0.26) and leaf number (0.21), as well as leaf length (-0.60) and leaf width (0.61) are closely related. Prin 3 and Prin 4 showed close relationship between leaf number (0.21, -0.74) and leaf width (0.17, 0.66) respectively compared to other growth characters of maize. The stem length (0.33) and leaf length (0.44) in Prin 5 are closely related.

4. DISCUSSION

The consistent increase in human population and global modernization has been considered as agents of industrialization [14,15]. Therefore, the huge benefits offered to mankind by these industries also come with a price during manufacturing processes. Most industrial plants generate wastewater which could become harmful to the environment [15,16]. The effect of liquid effluent produced on the continued food security especially in maize is of global concern.

Performances of the growth characters of maize treated with varying levels of effluent recorded increased growth compared to the control. This result affirm the investigation conducted by Medhi et al. [17] which reported that paper mill effluent at lower concentrations proved beneficial with significant effect on growth and development of rice, mustard and pea than control experiment which was treated with only water. However, negative trend was recorded in case of textile and dyeing effluents. The study of Ramana et al. [18] also reported similar positive effect of distillery effluent (raw spent wash) on the growth performance of onions, tomato, chilli, bottle gourd and cucumber at lower concentrations.

Growth rate increases with concentrations in this study contrary to some earlier results [17,18]. Based on earlier reports [14], at low concentration of pollutants in the effluents, the agricultural re-use of the treated effluent serves in promoting sustainable agriculture and conservation of scarce water resources while high concentrations have deleterious effect on plants. The polluted effluent water decreased germination of seeds by inhibiting enzyme action [19,20,21]. More so, the presence of heavy toxic metals in effluent may cause plasmolysis which may hinder plants' growth [22,23]. However, the polluted water could contain low concentrations of toxic metals, as well contains beneficial mineral elements as similarly observed by other researchers [20,21,24]. In the present study, the increase in growth at high concentration of effluent could be associated with the type of effluent used. The effluents could have both stimulatory as well as inhibitory effects, which also depends on the type of seed, genotype and concentrations of effluents [8,25]. The result was further validated by the study conducted by Challam and Chaturvedi [26] in which the height and yield of maize were reportedly increased significantly with 100% treated dairy effluent compared with 50%, 10% and control is in accordance with the findings of this study.

Variability response of maize genotypes to effluent treatments could be attributed to differences in genetic characteristics across the genotypes. Several studies had reported the resistance of maize genotypes to conditions such as; drought [27,28], pests [29], plant pathogens [4,30] and salt tolerance [31] among other stressors. Thus, genotypes TZM-1439 and TZM-29 used in this study were the most responsive genotypes to the non-alcoholic effluent. Although, the effect of genotypes and varying concentration levels of effluent recorded no significant association with growth characters, which could be due to their similar level of performances. Similar genetic differences on the morphological characters of maize genotypes had been reported [32] and genetic variability is considered a key to crop improvement [27,33]. The highest proportion and eigen vector in this study accounted for the variation of maize characters in PRIN 1 as similarly observed in the report of Olawuyi et al. [27] which confirmed the delineation of genotypes with respect to the alterations of effluent in the environment. This could be considered when planting in effluent polluted soils.

5. CONCLUSION

Generally, the effluent from non-alcoholic beverage company's treated maize plants recorded better growth performances at higher concentrations compared to the control experiment especially in the maize genotypes TZM – 1439 and TZM – 29.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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