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Original Article

Effect of Industrial Effluent on the Growth, Yield and Foliar Epidermal Features of Tomato (*Solanum lycopersicum* L.) in Jos, Plateau State, Nigeria

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Abstract

The impact of detergent effluent on the growth, yield and foliar epidermal characters of tomato (*Solanum lycopersicum* L.) was investigated. The variety of tomato ((ROMA VF) was grown on soil contaminated with different concentrations (5%, 10%, 15%, 20% and 25%) of the effluent. It was observed that the effluent affected the time of germination, flowering and fruiting of the tomato plant. The number and weight of fruits produced were also affected although the extent varied with concentrations. There were significant variations in the plant height, stem girth, number of leaves, number of fruits and weight of fruits among the different treatments at 0.05 level of probability. At lower effluent concentrations, it was observed that the growth and number of fruits were relatively higher than the control (plants not treated with the effluent). The foliar anatomical study on the tomato showed that the effluent affected the structures of the plants. Significant reductions were observed in the stomata density, trichome frequency and number of epidermal cells on both the adaxial and abaxial surfaces as the concentration increases. This study revealed that detergent effluent had significant effect on the growth, yield and the foliar anatomy of *Solanum lycopersicum* especially at higher concentration (25%).

Keywords: detergent effluent, germination, *Solanum lycopersicum*, stomata, trichome

Introduction

Effluents are wastes produced from industries and vary depending on the human activities that produce them. Production of these wastes is an integral part of industrial activities but unfortunately our inability to anticipate or predict the types and magnitude of undesired consequence of unbridled release of effluents in our environment, coupled with the growth of industrialization have resulted in massive and destructive operations in our ecosystems (Uaboi-Egbenni *et al*., 2009).

In Nigeria, waste waters from almost all the industries are discharged untreated either on land or into water bodies. Even at the places where some treatment facilities exist, these are not been operated properly. Resultantly, these waste waters pollute the water resources and ultimately the agricultural land (Arjun *et al*., 2013). It has been found that the growth and yield of crops and soil health get reduced when farmers use these polluted water for irrigation of the cultivated land (Nandy and Kaul, 1994). Most of the urban farmers in Nigeria divert treated or untreated effluent contaminated water to their farmlands for irrigation of especially vegetable farms to meet up with the rising demand for fresh vegetables in the country (Uaboi-Egbenni *et al*., 2009; Fatoba *et al*., 2011). However, there should be cautious use of such waters for irrigation of crops that are tender and herbaceous like vegetables (Ogunkunle *et al*., 2013).

Crops and vegetables grown in the agricultural fields irrigated by textile, detergent and other effluent contaminated waters are adversely affected both quantitatively and qualitatively. Impact of effluent on agricultural crops has been studied earlier by several workers (Angadi and Mathad, 1998; Srivastava and Purnima, 1999; Tomar *et al*., 2000). The influence of different

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concentration of heavy metals (Fe, Pb and Cu) found in effluents was investigated by Mammi *et al.* (2011) on the seed germination and growth of two varieties of tomato. They discovered that heavy metals in higher doses cause metabolic disorders and growth inhibition for both the plant species.

The use of industrial effluents could be a technical solution to reducing soil degradation through chemical pollution (Fatoba *et al.*, 2011) without considering the detrimental effects the chemical constituents of such effluents on the physiological processes, morphological and anatomical structures of such crops irrigated with the effluent (Wyszkowski and Wyszkowska, 2003; Kovacic and Nikolic, 2005).

Tomato (*Solanum lycopersicum* L.) a relatively short lived crop, is one of the most important vegetables worldwide (Seisuke and Neelima, 2008) and is grown in practically every country of the world in outdoor fields, greenhouses and net houses. Tomato belongs to the Solanaceae which also includes other well known species such as potato, tobacco, pepper and egg plant (Ayandiji *et al.*, 2011). The plant typically grows from 1-3 meters in height and has a weak stem that often sprawls over the ground and vines over other plants (Renato *et al*., 2014).

In Nigeria, tomato is cultivated almost throughout the country but the areas of high concentration lie in the northern and south-western parts. It is cultivated in small holdings under rain fed conditions in the southern parts and grown extensively under irrigation in the northern part (Ayandiji *et al.*, 2011).

Tomato is consumed fresh or processed into puree, paste, powder, ketchup, sauce and soup or canned as whole fruit (Blum *et al.*, 2005) and it has antioxidant components that are medically useful in the area of cataracts, bone metabolism and asthma (Freeman and Reimers, 2010). Tomato contributes to a healthy source of diet since it is a source of vitamins A, B and C and also contains a good amount of minerals such as potassium, iron and phosphorus (Charchar *et al.*, 2003). The daily intake of tomato provides the body some nutrients such as carotene and lycopene which lower the risk of cancer and cardiovascular disease (Bock *et al*., 1992).

Despite the importance of this crop, there are various production constraints wherever they are grown in the country, which include soil pollution with industrial effluents, diesel oil, transportation and accessibility to market. In Nigeria, vegetables are the cheapest and most readily available sources of important protein, vitamins, minerals and essential amino acids (Akubugwo *et al*., 2001). Therefore release of industrial effluents on agricultural land and water bodies is one of the factors that limits the increased production of vegetables especially *Solanum lycopersicum* and its primary cause of low quality and yield.

In Plateau state, farmers irrigate their gardens with water obtained from rivers and streams containing effluents from industries as a result of which toxic metals can be transferred and concentrated into plant tissues from the soil. This research was therefore conducted to determine the extent to which the growth, yield and the anatomical structures of plants are affected by these industrial effluents.

Materials and Methods

Experimental site

The experiment was conducted at the Botanical garden of the University of Jos, Plateau state, Nigeria to assess the effects of detergents effluents on the growth and yield of *Solanum lycopersicum*.

Source of seeds, detergent effluent and soil

The variety of the tomato (Roma VF) seeds was purchased at an agro-seed shop in Jos while the detergent effluent used was obtained from Nasco Household Limited, Jos. The top soil used in this study was obtained from the nursery of Federal College of Forestry, Jos, Nigeria.

Soil preparation

The Topsoil was sieved with a 2 mm mesh and 24 kg weighed and mixed with different volumes of effluent using hand trowel to get various homogeneous mixtures/ concentrations. 30 labelled, perforated nursery polythene bags were filled with 3 kg of the soil mixture to give five replications of each concentration respectively. The concentrations were determined as illustrated below:

0 ml of effluent + 24 kg of soil = control
250 ml of effluent + 24 kg of soil = 5% concentration
500 ml of effluent + 24 kg of soil = 10% concentration
750 ml of effluent + 24 kg of soil = 15% concentration
1000 ml of effluent + 24 kg of soil = 20% concentration
1250 ml of effluent + 24 kg of soil = 25% concentration

Seed sowing and wetting

Healthy seeds of *Solanum lycopersicum* were planted on the soil in each of the polyethylene pots and wetted every two days till the 16th week after planting (16 WAP) when the experiment was terminated.

Preparation of leaf epidermal surfaces

The preparation of leaf samples for permanent slides to enhance epidermal morphology followed the method of Wilkinson's (1979) with slight modifications to accommodate the peculiarity of the plant specimens. The leaf samples were soaked in 70% Sodium Hypochlorite for three to five hours in order to remove the colouring pigments and surface debris followed by washing in several changes of water to remove excess reagents. Using fine grade camel hair brush, epidermal peels were carefully removed from the leaf sample surfaces. The slides of both the adaxial and abaxial surfaces of the leaves were prepared, labelled, viewed for micromorphological characters with the digital Olympus BX 51 light microscope and photomicrographs were captured on the computer. For statistical analysis, five epidermal cells and five stomata were chosen at random from each species and measured using a micrometer. For each quantitative character, the range, mean, standard deviation and standard error were determined for each species.

Experimental design

The Completely Randomized Design (CRD) format was used for this research work, with six treatments and five

replications each. Data were collected on plant height, stem girth, number of leaves, number of fruits, weight of fruit (fresh and dry), weight of shoot and roots (fresh and dry). Data collected were subjected to analysis of variance (ANOVA) and the means separated using Least Significant Difference (LSD) and Duncan Multiple Range Test (DMRT) at 5% level of probability.

Results

Plant height

This investigation revealed that responses of *Solanum lycopersicum* grown in different levels of concentration of industrial effluent appear to be dose dependent. The results at 4, 8, 12 and 16WAP (Weeks After Planting) showed that plant height differed within the different levels of concentration with 5% level of contamination having the highest height while the control (0% concentration) had the least height. Statistically, 5% level of concentration produced significantly higher height at 0.05 level of probability than the other levels of concentration. Across the weeks, the heights of the control plants showed no significant differences while the plants of the other concentrations showed significant differences (Table 1).

Stem girth

The investigation showed that the highest stem girth of *Solanum lycopersicum* was recorded in the plants grown without the effluent (control) while the plants with 25% level of concentration had the least stem girth. Increasing the concentration of effluent from 0% to 20% concentration at 4WAP did not show any significant difference while 25% level of contamination was significantly different from all other levels of contamination at 0.05 level of probability. There was significant difference across all the concentrations at 8WAP while 12WAP and 16WAP showed no significant difference. Statistically, there was no significant difference across the weeks for all effluent concentrations at 0.05 level of probability (Table 2).

Number of leaves

The effluent had an effect on the number of leaves as it showed significant difference with increase in the concentration of effluent. However, there was a significant reduction in the number of leaves in 25% level of concentration as compared to those grown at lower concentrations. Statistical analysis showed that the number of leaves at 4 WAP differ significantly across the treatments. The 5% level of concentration differ across the different weeks while the number of leaves do not differ significantly across the weeks in other level of concentrations at 0.05 level of probability (Table 3).

Number of fruits

Fruiting was recorded from the 12th week after planting. The fruit production was highest in 20% level of concentration and least in the control. Statistically, it was

Table 1. Plant height (cm) of *Solanum lycopersicum* treated with different concentrations of detergent effluent

Effluent Concentration (%)	4 WAP	8 WAP	12 WAP	16 WAP	$LSD_{0.05}$
Control	12.82	26.32	31.06	32.94	9.40
5	10.32	35.36	59.38	65.34	
10	9.82	28.36	50.62	56.18	
15	6.90	26.06	45.80	50.02	
20	6.06	26.18	47.58	53.10	
25	4.48	17.44	32.94	38.18	

Pairs of means that differ by more than their LSD are significantly different at 5% level of significance.

Table 2. Stem girth (cm) of *Solanum lycopersicum* treated with different concentrations of detergent effluent

Effluent Concentration (%)	4 WAP	8WAP	12 WAP	16 WAP	$LSD_{0.05}$
Control	1.12	2.10	2.16	2.22	2.31
5	1.08	1.98	2.20	2.26	
10	1.02	1.92	2.10	2.18	
15	0.86	1.68	2.10	2.20	
20	0.74	1.72	2.18	2.28	
25	0.44	1.02	1.94	2.14	

Pairs of means that differ by more than their LSD are significantly different at 5% level of significance.

Table 3. Number of leaves of *Solanum lycopersicum* treated with different concentrations of detergent effluent

Effluent Concentration (%)	4 WAP	8 WAP	12 WAP	16 WAP	$LSD_{0.05}$
Control	9.00	48.00	71.20	71.00	12.02
5	17.80	70.20	119.20	103.00	
10	14.00	45.00	83.20	75.80	
15	9.40	44.80	88.40	67.20	
20	10.60	47.60	88.20	76.60	
25	6.80	33.60	60.40	63.00	

Pairs of means that differ by more than their LSD are significantly different at 5% level of significance.

observed that 20% level of concentration had the highest yield from 12WAP to 16WAP when compared with mean number of fruits from those grown in other concentrations including the control and differ significantly at 0.05 level of probability while the control had the lowest yield when compared with other level of concentration and differ significantly from other level of contaminations at 0.05 level of probability (Table 4).

Weight of shoot

The least mean fresh shoot weight was recorded in the control and the highest was recorded at 20% level of concentration. Statically, the mean dry shoot weight of plants at the 15% and 20% levels of concentration differed significantly from the plants grown at other levels of concentration including the control. Similarly, the least mean dry shoot weight was recorded in the control while the 20% level of concentration showed the highest dry shot weight (Table 5).

Weight of root

Plants grown with 25% level of concentration of the effluent had the least mean fresh root while pants at 20% level of concentration had the highest mean root weight. Statistical analysis revealed that plants grown in 20% level of concentration were significantly different from plants grown in other levels of concentration including the control. Also, the dry weight of roots was highest at 20% level of concentration while 5% and 25% levels of concentration had the least dry weight of roots. Statistically, the plant grown with 20% level of concentration of the effluent was significantly different from those grown on the levels of concentration with exception to 15% level of concentration (Table 6).

Weight of fruits

The research revealed that the highest fresh weight of fruits was recorded in plant grown in 20% level of concentration of the effluent while the control had the last weight. Similarly, the highest dry weight of fruit was recorded in the 20% level of concentration and the control had the least dry weight. There was a significant difference across the treatments studied (Table 7).

Variation in the epidermal features of the leaves of Solanum lycopersicum

The leaves were hypostomatic having stomata only on the abaxial (lower) surface in all the treatments (control, 5%, 10%, 15%, 20% and 25% effluent concentrations). The actinocytic stomata type (stomata surrounded by four or

Table 4. Number of fruits of *Solanum lycopersicum* treated with different detergent effluent concentrations

Effluent Concentration (%)	12 WAP	14 WAP	16 WAP	$LSD_{0.05}$
Control	0.00	0.00	0.60	0.29
5	1.60	2.00	2.40	
10	2.00	2.20	2.60	
15	1.60	1.80	2.60	
20	2.20	2.60	3.60	
25	1.40	2.20	2.40	

Pairs of means that differ by more than their LSD are significantly different at 5% level of significance.

Table 5. Fresh and dry weight of shoot of *Solanum lycopersicum* treated with different concentrations of effluent at 16WAP

Effluent Concentration (%)	Fresh Shoot Weight (g)	Dry Shoot Weight (g)
Control	7.60^{a}	0.71^{a}
5	9.12^{a}	0.82^{a}
10	9.25^{a}	0.83^{a}
15	12.54^{b}	1.16^{b}
20	13.98^{b}	1.32^{b}
25	8.89^{a}	0.90^{a}
DMRT	2.48	0.22

Means followed by same letter(s) within treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT)

Table 6. Fresh and dry weight of root of *Solanum lycopersicum* treated with different concentrations of effluent at 16WAP

Effluent Concentration (%)	Fresh Root Weight (g)	Dry Root Weight (g)
Control	2.94^{a}	0.34^{a}
5	2.17^{a}	0.21^{a}
10	2.44^{a}	0.22^{a}
15	3.13^{a}	0.34^{ab}
20	4.07^{b}	0.42^{ab}
25	2.05^{a}	0.21^{a}
DMRT	1.76	0.15

Means followed by same letter(s) within treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

Table 7. Fresh and dry weight of fruits of *Solanum lycopersicum* treated with different concentrations of effluent at 16WAP

Effluent concentration (%)	Fresh fruit weight (g)	Dry fruit weight (g)
Control	1.01[a]	0.11[a]
5	14.97[ad]	1.56[b]
10	17.45[ac]	1.91[eb]
15	17.76[ad]	1.94[d]
20	23.15[c]	2.34[c]
25	19.86[b]	2.02[eb]
DMRT	4.87	0.32

Means followed by same letter(s) within treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

Table 8. Qualitative foliar characters of the studied *Solanum lycopersicum* treated with different concentrations of effluent

Effluent Conc. (%)	Epidermal cell shape		Anticlinal wall pattern		Stomata type		Trichome type	
	Abaxial	Adaxial	Abaxial	Adaxial	Abaxial	Adaxial	Abaxial	Adaxial
Control	Irregular	Polygonal	Wavy	Curved	Actinocytic	-	Unicellular uniseriate	Unicellular uniseriate
5	Irregular	Polygonal	Wavy	Curved	Actinocytic	-	Unicellular uniseriate	Unicellular uniseriate
10	Irregular	Polygonal	Wavy	Curved	Actinocytic	-	Unicellular uniseriate	Unicellular uniseriate
15	Irregular	Polygonal	Wavy	Straight/ slightly curved	Actinocytic	-	Unicellular uniseriate	Unicellular uniseriate
20	Irregular	Undulate	Wavy	Straight/ slightly curved	Actinocytic	-	Unicellular uniseriate	Unicellular uniseriate
25	Irregular	Undulate	Wavy	Straight/ slightly curved	Actinocytic	-	Unicellular uniseriate	Unicellular uniseriate

Table 9. Quantitative foliar characters of the studied *Solanum lycopersicum* treated with different concentrations of effluent

Effluent Concentration	Stomata Measurement Min. (mean±S.E) max.		Epidermal Measurement Min. (mean±S.E) max.		Stomata index
	Length(μm)	Width (μm)	Length(μm)	Width (μm)	%
Control Abaxial Adaxial	9.50 (10.74±0.31) 11.94	1.01 (1.80 ± 0.22) 2.70	55.12 (58.56 ± 1.14) 62.62 52.70 (59.90 ± 1.29) 61.50	25.80 (29.02 ± 0.77) 32.01 25.60 (28.56 ± 0.75) 31.50	30.08
5% Abaxial Adaxial	8.50 (9.93 ± 0.32) 11.24	1.08 (1.50 ± 0.12) 2.04	47.64 (57.54 ± 1.82) 62.65 53.00 (59.02 ±1.20) 62.93	22.10 (27.06 ± 1.06) 31.30 24.50 (28.42 ± 0.80) 31.62	19.15
10% Abaxial Adaxial	8.83 (10.04 ± 0.29) 11.25	1.06 (1.70 ± 0.17) 2.47	51.30 (56.98 ±1.51) 62.90 51.72 (58.16 ±1.38) 59.61	25.51 (27.54 ± 0.68) 30.61 24.01 (28.60 ± 0.87) 30.94	15.78
15% Abaxial Adaxial	8.50 (9.92 ±0.29) 10.96	0.73 (1.70 ± 0.23) 2.72	56.14 (58.08 ±1.01) 61.23 51.40 (58.34 ± 1.42) 61.24	25.51 (27.00 ± 0.41) 28.62 21.16 (27.94 ± 1.29) 31.37	15.49
20% Abaxial Adaxial	6.81 (10.04 ± 0.80) 13.66	1.40 (1.58 ± 0.08) 2.03	54.40 (57.46 ± 0.92) 61.90 47.60 (57.26 ± 1.96) 62.90	25.50 (27.80 ± 0.58) 28.60 23.80 (26.38 ± 1.13) 31.31	17.50
25% Abaxial Adaxial	6.12 (9.64 ± 0.84) 12.90	0.64 (1.28 ± 0.17) 2.02	52. 45 (57.04±1.08) 61.55 51.20 (55.34 ± 1.33) 61.21	20.44 (24.54 ± 0.81) 27.21 24.50 (26.80 ± 0.55) 30.92	14.49

more subsidiary cells, elongated radically to the stomata) was seen in all the treatments. This showed that the effluent had no effect on the stomata type found on the surfaces of the leaves. The stomatal density differs in the treatments with the control having the highest stomatal density. The density reduced in the 5%, 10%, and 15% levels of concentration and increased in the 20 % but there was a reduction in the 25% level of concentration. The effluent had an effect on the stomatal size such that reductions were observed from the 5% level on concentration. The stomata index was highest in the control and reduced in 5%, 10% and 15% levels of concentration. In the 20% level of effluent concentration, the stomata index increased but there was a reduction in the 25% level of concentration (Table 9). The shape of the epidermal cells observed on the abaxial leaf surface of all the treatments (control, 5%, 10%, 15%, 20% and 25% effluent concentrations) was irregular (Table 8). Polygonal cell shape was observed on the adaxial (upper) leaf surface of the control and the lower effluent concentrations (5%, 10% and 15%) while undulate cell shape was observed on the leaves with higher effluent concentrations (20%, 25%). This shows that the effluent had effect on the

epidermal cell shape at higher effluent concentrations. The number of epidermal cells differs in all the treatment on both the adaxial and adaxial surfaces. The control had the highest number of cells while reductions were observed from the 5% level of effluent concentration. This shows that the effluent had effect on the number of epidermal cells on both leaf surfaces (the higher the concentration of the effluent, the lower the number of epidermal cells present). The anticlinal wall pattern was wavy on the abaxial leaf surface in all the treatments while on the adaxial surface, a straight pattern was seen in the control and lower concentrations (5%, 10% and 15%) while curved anticlinal pattern was observed in the higher concentrations (20% and 25%). Unicellular uniseriate trichomes were seen on both the abaxial and adaxial surfaces in all the treatments. The trichome density varies in the treatments with the 5% level of effluent concentration having the highest on both surfaces.

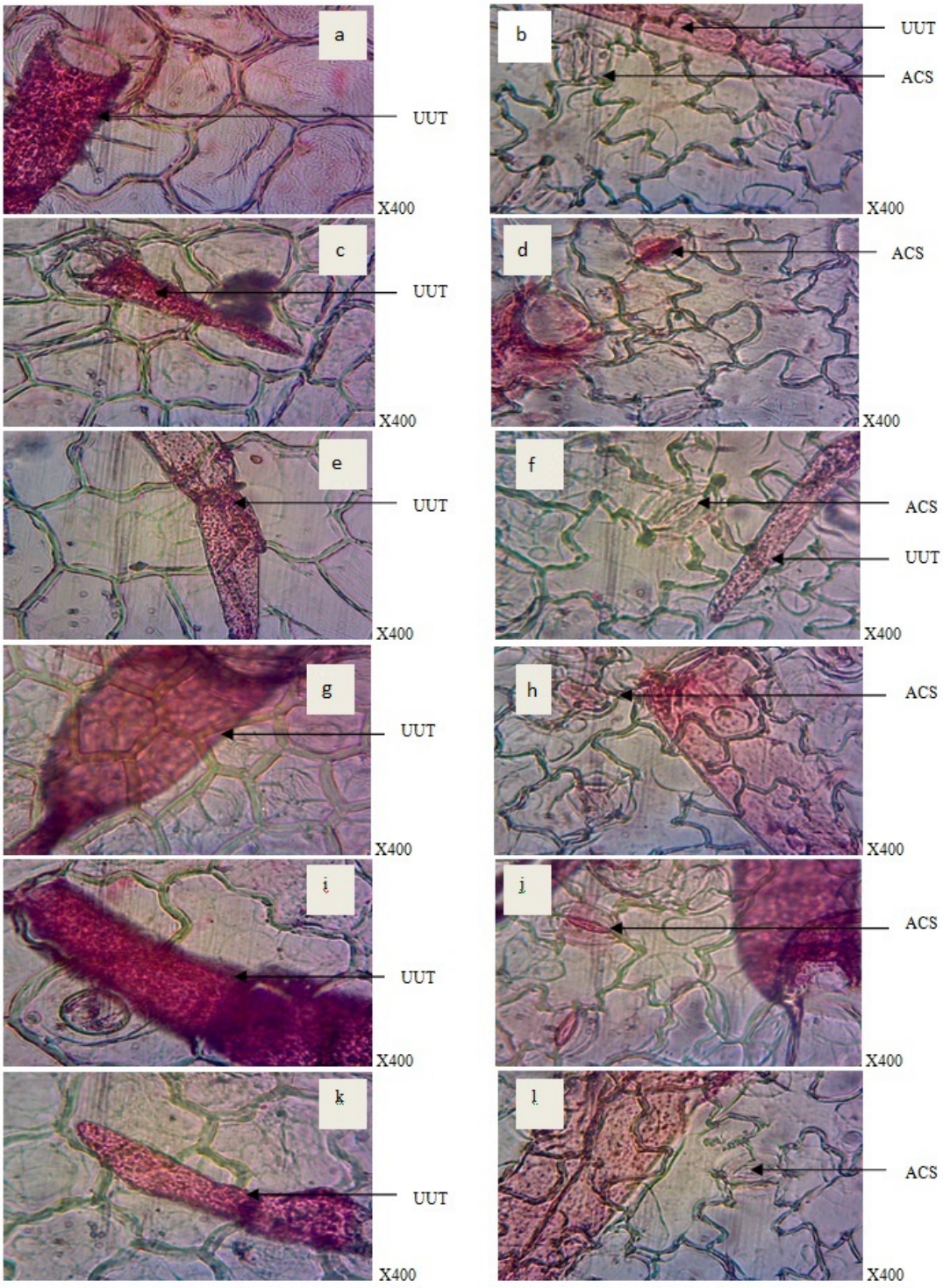

Fig. 1. Leaf epidermal features of *S. lycopersicum* showing Unicellular uniseriate trichome (UUT) and actinocytic stomata (ACS) in adaxial surfaces of leaf treated with 0%, 5%, 10%, 15%, 20% and 25% concentration of effluent (a,c,e,g,i,k) and abaxial surfaces of leaf treated with 0%, 5% 10%, 15%, 20% and 25% concentration of effluent (b,d,f,h,j,l)

Discussion

This investigation showed that the detergent effluent contaminations affected the growth parameters of *Solanum lycopersicum* positively with lower concentrations as shown by increased biomass, plant height, stem girth, number of leaves, number of fruits, weight of fruits (fresh and dry), weight of shoot (fresh and dry) and weight of root (fresh and dry). This study recorded the progressive increase in the values of the growth parameters of *Solanum lycopersicum* as effluent concentration increased from 5% to 20% concentration but there was a reduction in the growth parameters at 25% concentration, this could be as a result of changes in soil condition imposed by plant growth element that may be present in the effluent in agreement with the findings of Mammi *et al*. (2011).

It is evidently clear from the study that low concentration of the detergent effluent can be non-toxic to tomato growth but increasing concentration can be adversely toxic which possibly may translate to low biomass production. This is true as the first field work which ranges from 25% to 100% level of contamination died after germination with the exception of 25% concentration as also reported by Clement *et al.* (2013).

The leaf epidermis of *Solanum lycopersicum* showed different responses to the various concentrations of the detergent effluents. There was no difference in the structure of trichome of the leaf epidermis in all the concentrations. This had also been reported by Ogunkunle *et al*. (2013) and Omosun *et al.* (2008) in *Amarantus hybridus* irrigated with pharmaceutical effluents and crude oil. Stomata density, number of epidermal cells and trichome density differed significantly on the two surfaces of all the concentrations. The effluent affected the stomata density, trichome frequency and number of epidermal cells of the leaves. Significant reduction of the stomata, trichome density and number of epidermal cells were observed as from 5% to 25% effluent treatments. Control had the highest stomata index while 25% effluent treatment recorded the least. This could be as a result of the grossly effect of the effluent. This is in agreement with findings of Omosun *et al*. (2008) who reported low stomata index in the plants treated with pharmaceutical effluent. The toxic effect of the detergent was observed from 5% to 25% effluent concentrations in the form of reduction of trichome density and number of epidermal cells on both surfaces, this perhaps may be a strategy to reduce stress from physiological processes on the adaxial surface since it is the surface receiving much of the solar radiation and engage in photosynthesis more. This had been previously affirmed by Esau (1965) that the degree of sinuosity of epidermal cells was premised on the extent of impact exerted on the stomata in the course of developmental process.

The stomata density increased significantly at 20% concentration. This could be as a result of modification of *Solanum lycopersicum* to survive in the polluted soil by replenishing dead stomata due to the toxic effects of the effluents, increase in stomata density can be considered as an adaptability indicator to a polluted environment (Kapitonova, 2002; Gostin, 2009; Ogunkunle *et al*., 2013). This modification was not possible by *Solanum lycopersicum* grown on 25% effluent concentrations due to the high toxicity effect of the effluent.

Conclusions

This study revealed that low concentration of detergent effluents could be well utilized for agricultural crops so as to reduce the lethality of the pollutants. Untreated industrial effluent creates serious hazards to plants and eventually to human health. It may be further concluded that the higher concentration of released detergent effluent causes various types of inhibitory effects on the plant growth, crop yield, anatomical structure and poor human health. Furthermore, these visible significant changes seen in all the *Solanum lycopersicm* grown in effluent contaminated soil could be employed as an index of monitoring environmental pollution.

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