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Anatomical Variations Caused by the Exposure of Sodium Azide and Potassium Chromate to the Accessions of *Colocasia esculenta* (L.) and *Xanthosoma maffafa* (L.) in Nigeria.

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ABSTRACT

The anatomical variations of the mid ribs and petioles of five accessions of *Colocasia esculenta* L. and three accessions of *Xanthosoma maffafa* L. exposed to different concentrations of sodium azide and potassium chromate were carried out. Graded quantities of 2.5, 5, 7.5 and 10 mg/kg of sodium azide and potassium chromate were applied to each accession while the control experiment lacked the oil-field chemical additives. Results showed some variations in the shape of epidermal cells, thickness of cuticle and number of vascular tissues among others. The petioles were observed to have more vascular tissues than the mid ribs for both the control and treated accessions. Statistical evidence showed that differences in the number of vascular tissues between various accessions and treatments were highly significant at 5 % probability. Between these two oilfield chemicals, it was observed that sodium azide treatments induced formation of more vascular tissues in both the mid ribs and petioles than potassium chromate treatments. These observations add to the literature and the understanding of this species' mechanism in withstanding environmental stress.

Keywords: Sodium azide, potassium chromate, *Colocasia*, *Xanthosoma*, accessions, vascular tissues, epidermal cells, oxalate crystals

1. INTRODUCTION

With the industrial revolution in Nigeria comes pollution which gets worse by the day as technological advancement progresses. Since the onset of the oil boom in the Nigeria, so much environmental degradation has been recorded with little or no intervention by the government. Kloff and Wicks (2004), reported that during drilling operation, one production platform may discharge about 60,000 $m^3$of drilling fluids into the environment. Sodium azide and potassium chromate are examples of chemicals used in such operations. Plant systems have proven to be sensitive and effective in ecotoxic examinations (Abu, 2012) because, they are the first structures to be exposed to chemicals in both water and soil (Odeigah *et al*., 1997). Consequently, plants have been used as bioassay to study environmental chemicals with mutagenic and carcinogenic potentials (Nkwocha and Duru, 2010 and Ohanmu *et al*., 2014).

Exploitation of modifications of anatomical characters of plants for environmental monitoring has been carried out with *Cydnodon dactylon* (Hameed *et al*., 2010), *Gazania harlequin* (Younis *et al.*, 2010) and *Abutilon indicum, Croton sparsiflorus* and *Cassia occidentalis* (Sukumaran, 2014). Dias *et al.* (2014), believed that the anatomy of plants contribute to our understanding of the physiological and structural changes they undergo thereby, providing information on how they adapt to their dynamic environment.

Plants therefore, are ideal test objects for the determination of anthropogenic chemical loading of the water body and the environment in both native and modelling conditions (Ilyashenko *et al*., 2014).

Colocasia esuelenta (taro or cocoyam in Nigeria) and *Xanthosoma maffafa* (tannia or also cocoyam in Nigeria) belong to the Araceae family. They are the third most important root crops in Nigeria and are known as Nigeria's giant crop (Chukwu, 2011). They are cultivated and consumed mainly in the South-east and South-south regions of Nigeria; they recently found uses in phyto-medicine (Chukwu, 2014), food and biotechnology industries (Owusu-Darko *et al*., 2014), biofuel (Adelekan, 2012). Cocoyam research has received minimal attention when compared to other important root crops (yam and cassava) in Nigeria; to this effect, we wish to contribute to the literature and understanding of this plant.

The aim of this study therefore, is to examine the effects of sodium azide and potassium chromate on the anatomy of *C. esculenta* and *X. maffafa* accessions; and to access the responses and adaptive mechanisms of these accessions to oilfield chemical stress.

2. MATERIALS AND METHODS

This experiment was carried out in the Ecological Research Centre, University of Port Harcourt. Polythene bags containing 10 kg soil were used for the planting. A total of eight accessions were used for this study. They include five accessions of *Colocasia esculenta* (NCe 001, NCe 002, NCe 003, NCe 004 and NCe 005) and three accessions of *Xanthosoma maffafa* (NXs 001, NXs 002 and NXs 003). All the plant samples were identified and collected from the National Root Crops Research Institute (NRCRI), Umudike. Each accession was exposed to four (4) different concentrations (2.5, 5, 7.5 and 10 mg/kg) of sodium azide and potassium chromate while the control experiment was not exposed to oil field chemicals treatment.

The chemicals were applied by mixing each concentration with 400 ml of water. This mixture was used in watering the plants immediately after planting. Further irrigation of the plants was done twice with 200 ml of water as there was sufficient rainfall throughout the duration of this work. Weeding was by hand-picking.

Anatomical sections of the mid ribs and petioles of the control and treated accessions were made by free-hand sectioning. The sections were stained with 0.1 % safranin or methylene blue solution for 5 minutes. The stained sections were washed to remove excess stain and mounted in a drop of 100 % glycerine on a clean glass slide and covered with No. 1 cover slips. The preparations were microscopically examined and micrographs were taken to show the anatomical features of interest.

Numerical data generated from the study were exposed to analysis of variance (ANOVA) and the means were compared using the Duncan's multiple range test (DMRT) at 5 %.

3. RESULTS AND DISCUSSION

Midrib: The mid ribs of these two species were dorsiventral (Plate 1a) with uniseriate compactly arranged thinly cuticularised upper and lower epidermes (Plate 1c-d). The epidermes of *C. esculenta* accessions were mostly rectangular to barrel shaped (Plate 1c) while those of *X. maffafa* accessions were generally round to convex in shape. Underlying the epidermis was a uniseriate layer of isodiametric chlorenchyma cells with parietal chloroplasts. The mesophyll was not differentiated into palisade and spongy types. Variable number of round-to-oval collateral closed vascular bundles (as many as 14 to 35) were observed in the ground tissue of the midrib. A few conjoined vascular tissues (Plate 2) were observed in accession NXs 003. Laticifers (Plate 3g) and aerenchyma were few to numerous in *X. maffafa* accession NXs 002. Oxalate crystals were observed to be projecting into the laticifers. The oxalate crystals observed include raphides, druses and styloid types (Plate 3). Two major types of raphides were observed. These crystals were very conspicuous in *X*. *maffafa* accessions than in *C. esculenta* accessions.

The epidermal cells of 2.5 mg/kg Sodium azide-treated pants were barrel instead of convex shaped. More oxalate crystals were observed with 5, 7.5 and 10 mg/kg treatment of sodium azide. On the other hand, oxalate crystals were recorded in the midrib of plants exposed to 10mg/kg potassium chromate treatment.

NCe 002 control had barrel shaped epidermal cells, no oxalate crystal and 16 vascular tissues. Tissues in this accession were not affected except for the number of vascular bundles that ranged from 23 to 31 in sodium azide and 13 to 21 in potassium chromate treatments.

NCe 003 control had barrel shaped epidermis, oxalate crystals and 17 vascular tissues. Sodium azide and potassium chromate treatments caused the absence of oxalate crystals in this accession, while 2.5 mg/kg of potassium chromate treatment induced a change of the outer shape of the epidermal cells to convex. The number of vascular tissues were not affected so much as they were observed to range from 15 to 16 in sodium azide treatments and 14 to 17 in potassium chromate treatments.

NCe 004 control had barrel shaped epidermal cells, no oxalate crystals and 14 vascular tissues. Sodium azide treatment altered the number of vascular tissues ranging from 6 to 36 and potassium chromate treatments changed the vascular tissues numbers ranging from 13 to 15. Sodium azide treatment with 7.5mg/kg concentration also induced the presence of oxalate crystals in this accession.

NCe 005 control had barrel shaped epidermal cells, oxalate crystals and 16 vascular tissues. Potassium chromate treatments with 5, 7.5 and 10mg/kg changed the shape of epidermal cells to convex, induced the absence of oxalate crystals. Sodium azide treatments with 2.5 and 7.5mg/kg also changed the epidermal cells to convex shape. 16 to 25 vascular tissues were observed in sodium azide treatments while 16 to 25 vascular tissues were counted in potassium chromate treated accessions.

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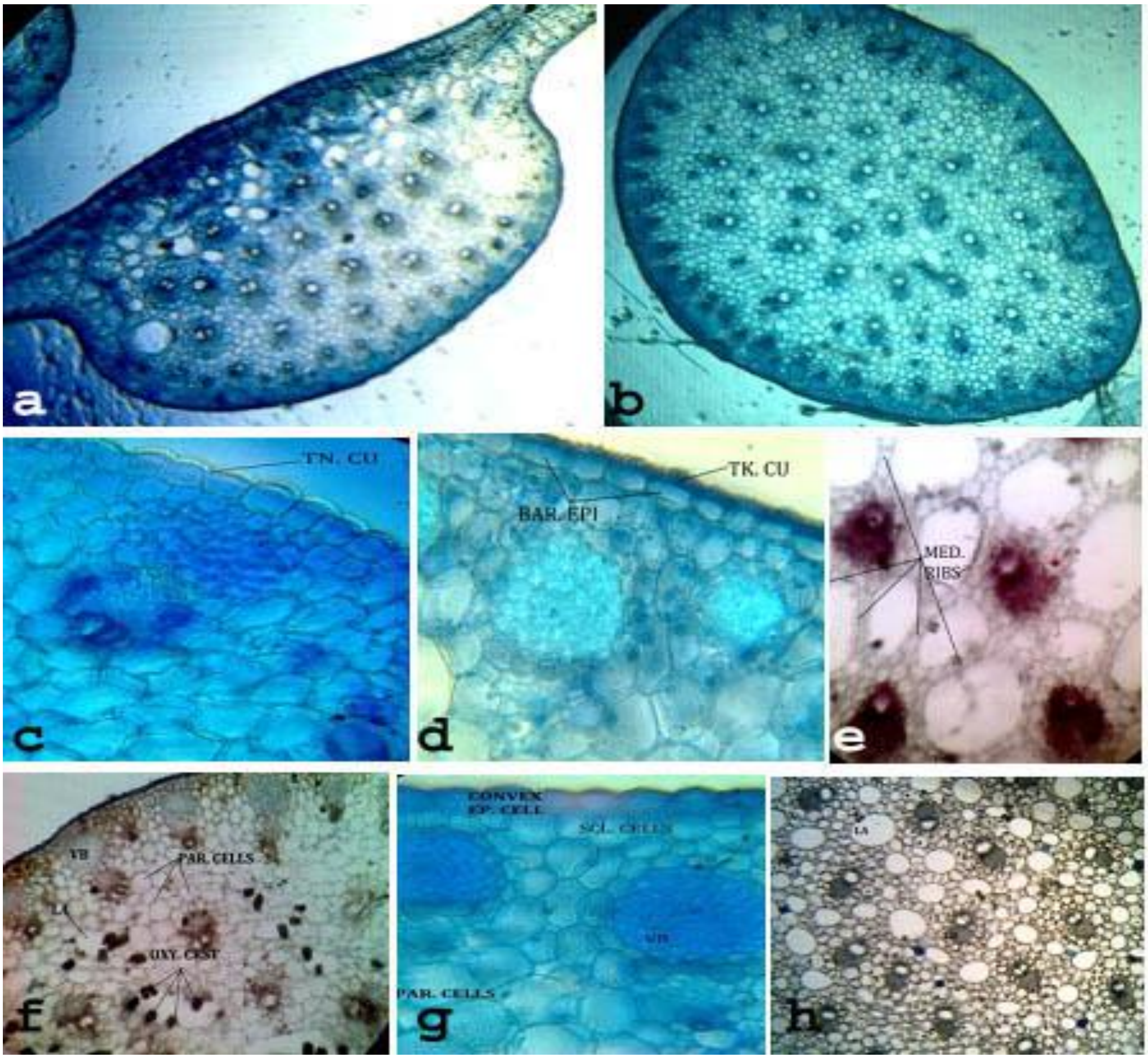

Plate 1: Transverse sections of the Mid rib and Petiole a) midrib, b) petiole), c-e) closer views of the midrib, c) Abaxial part of midrib of untreated plant showing thin-walled epidermis, d) Abaxial part of midrib of treated plant showing thickly cuticularised epidermis with barrel shaped epidermal cells, e) medullary ribs at the adazial part of the midrib, f) Petiole of treated plants showing thickly cuticularised surface and numerous oxalate structures at the laticifers within the ground tissue, g) Outer surface of the petiole of control plant and h) ground tissue of the petiole of showing numerous laticifers and ground tissues (Keys= MED. RIBS= medullary ribs, CONVEX. EP. CELLS = convex epidermal cells, SCI. CELLS= sclerenchyma cells, VB= vascular bundle, PAR. CELLS= parenchyma cells, TK. CU= thick cuticle, TN. CU= thin cuticle, BAR. EPI= barrel shaped epidermal cells, LA= laticifer, OXY. CRST= oxalate crystals)

NXs 001 control had convex shaped epidermal cells, oxalate crystals and 24 vascular tissues. Sodium azide treatment with 10mg/kg induced the absence of oxalate crystals in this accession. Conjoined vascular tissues was observed in 5mg/kg of potassium chromate treatment, 13 to 36 vascular tissues were counted in potassium chromate treatments while 21 to 31 vascular tissues were counted in sodium azide treated accessions.

NXs 002 control had convex shaped epidermis, medullary ribs, oxalate crystals and 27 vascular tissues. In sodium azide treated accessions, medullary ribs were absent while 17 to 31 vascular tissues were observed. Potassium chromate treatments with 2.5, 7.5 and 10mg/kg caused total absence of medullary ribs, and 17 to 30 vascular tissues were observed with this treatment.

NXs 003 control had convex shaped epidermal cells, no medullary ribs and oxalate crystals and 28 vascular tissues were observed. Oxalate crystals were observed in all sodium azide and potassium chromate treatments, the presence of medullary ribs were observed with 5mg/kg sodium azide treatments and with 5 and 10mg/kg potassium chromate treatments. Conjoined vascular tissues were absent in all treatment concentrations except in 7.5mg/kg of sodium azide treatment, 27 to 53 vascular tissues were observed in sodium azide treatments while 36 to 56 vascular tissues were observed in potassium chromate treatments.

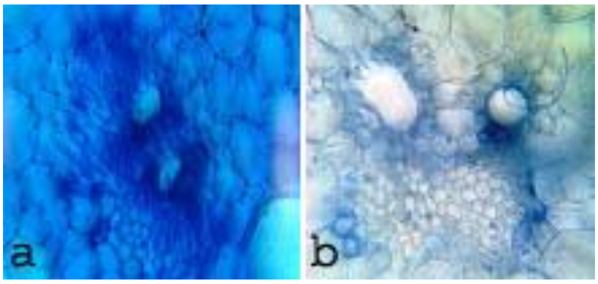

Plate 2: Conjoined vascular tissues/bundles

Cuticles of the treated accessions were thicker than the cuticles from the control accessions. The number of vascular bundles (Table 1) was one component in the mid rib that differentiated one accession and one treatment concentration from another. It was observed that the treatments decreased the mean number of vascular tissues in accessions NCe 001, NCe 003, NCe 004 and NXs 002 when compared with their respective controls. Meanwhile, the treatments increased the mean number of vascular bundles in accessions NCe 002, NCe 005, Nxs 001 and NXs 003 when compared with their controls. Furthermore, sodium azide treatment (Figure 1) increased the mean number of vascular bundles compared to potassium chromate treatment. Statistical evidence also showed that the difference in the number of vascular tissues between accessions and treatments was also highly significant at 5 %.

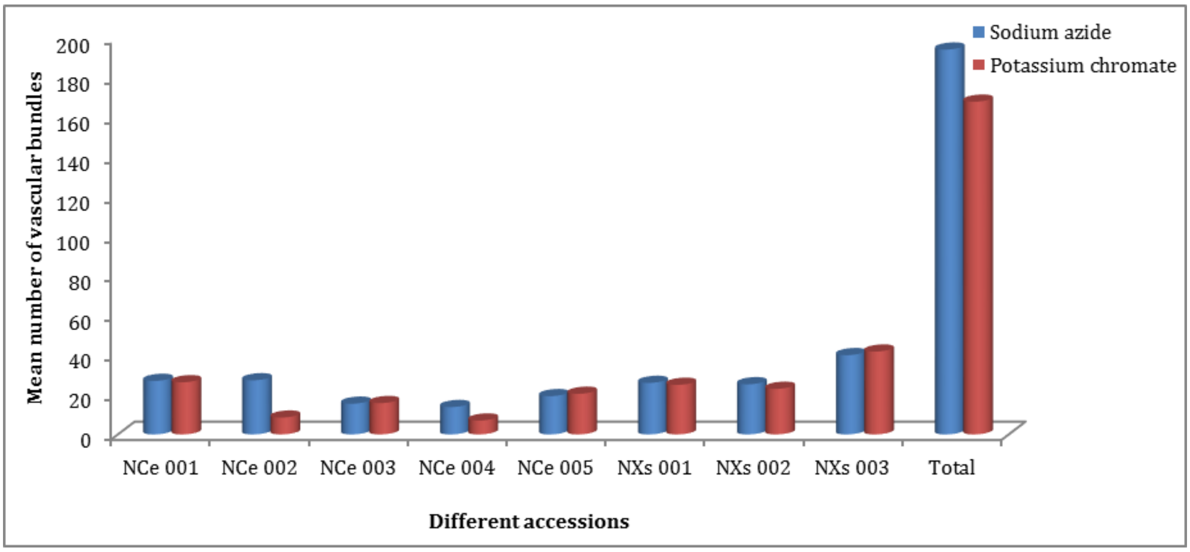

Figure 1: Effects of sodium azide and potassium chromate treatments on the mean number of vascular bundles in the mid rib

Table 1: Effects of sodium azide and potassium chromate on the number of vascular bundles on mid ribs and petioles of different accessions

Chem. treatment	Conc. (mg/kg)	Organ	NCe 001	NCe 002	NCe 003	NCe 004	NCe 005	NXs 001	NXs 002	NXs 003
Sodium azide	2.5	Mid rib	14^{abcd}	26^{abcd}	16^{abcd}	0^{abcd}	18^{abcd}	31^{abcd}	30^{abcd}	53^{abcd}
		Petiole	30^{efgh}	63^{efgh}	42^{efgh}	0^{efgh}	44^{efgh}	49^{efgh}	49^{efgh}	59^{efgh}
	5	Mid rib	30^{abcd}	31^{abcd}	15^{abcd}	6^{abcd}	16^{abcd}	22^{abcd}	17^{abcd}	38^{abcd}
		Petiole	36^{efgh}	61^{efgh}	34^{efgh}	21^{efgh}	35^{efgh}	34^{efgh}	46^{efgh}	70^{efgh}
	7.5	Mid rib	43^{cd}	23^{cd}	15^{cd}	36^{cd}	25^{cd}	21^{cd}	23^{cd}	42^{cd}
		Petiole	53^{i}	45^{i}	32^{i}	95^{i}	39^{i}	33^{i}	40^{i}	68^{i}
	10	Mid rib	21^{abcd}	29^{abcd}	16^{abcd}	13^{abcd}	18^{abcd}	30^{abcd}	31^{abcd}	27^{abcd}
		Petiole	45^{hi}	59^{hi}	29^{hi}	41^{hi}	45^{hi}	52^{hi}	52^{hi}	50^{hi}
Potassium chromate	2.5	Mid rib	25^{abcd}	21^{abcd}	15^{abcd}	15^{abcd}	20^{abcd}	31^{abcd}	26^{abcd}	39^{abcd}
		Petiole	32^{ghi}	54^{ghi}	33^{ghi}	36^{ghi}	50^{ghi}	39^{ghi}	46^{ghi}	58^{ghi}
	5	Mid rib	30^{abc}	0^{abc}	17^{abc}	13^{abc}	16^{abc}	36^{abc}	17^{abc}	36^{abc}
		Petiole	40^{d}	0^{d}	28^{d}	30^{d}	31^{d}	41^{d}	23^{d}	45^{d}
	7.5	Mid rib	28^{efgh}	0^{efgh}	14^{efgh}	0^{efgh}	20^{efgh}	20^{efgh}	30^{efgh}	36^{efgh}
		Petiole	44^{efgh}	0^{efgh}	41^{efgh}	0^{efgh}	36^{efgh}	38^{efgh}	89^{efgh}	66^{efgh}
	10	Mid rib	22^{abc}	13^{abc}	17^{abc}	0^{abc}	26^{abc}	13^{abc}	19^{abc}	56^{abc}
		Petiole	33^{bcd}	32^{bcd}	36^{bcd}	0^{bcd}	37^{bcd}	17^{bcd}	16^{bcd}	52^{bcd}
Control	0	Mid rib	35^{abcd}	16^{abcd}	17^{abcd}	14^{abcd}	16^{abcd}	24^{abcd}	27^{abcd}	28^{abcd}
		Petiole	50^{fghi}	40^{fghi}	54^{fghi}	38^{fghi}	32^{fghi}	46^{fghi}	34^{fghi}	51^{fghi}

Values with different superscripted alphabets within column are significantly different at 5 %, values with similar superscripted alphabets within a column are not significantly different at 5 %

Petiole: The petioles of these two species were spherical in transection (Plate 1b, f-h) with uniseriate thinly cutinized epidermal cells. The epidermis of *C. esculenta* accessions were generally rectangular to barrel shaped while the epidermis of *X. maffafa* accessions were generally round to convex in transverse outline (Plate 1f). Immediately underlying the epidermis was the hypodermis composed of 1 to 2 layers of sclerenchymatous cells. Collateral vascular bundles were observed just after the hypodermis and were spherically arranged. These vascular bundles were oval to round in shape and were also scattered at the ground tissues; conjoined vascular bundles were also observed in accession NXs 003. Vascular bundles were observed to be the major differentiating tissue in this organ; as many as 32 to 54 vascular tissues were observed in the accessions of these two species. The ground tissue was composed of closely packed parenchymatous cells with laticifers; in *X. maffafa* accessions, the ground tissues have network-like structures of parenchymatous medullary rays similar to those in the upper part f the midrib (Plate 1e) with oxalate crystals deposited at the laticifers and at the aerenchymatous tissues (Plate 1f,h). The raphide, styloid and druse types of oxalate crystals were all present in this study but the raphide type of oxalate crystal was observed to be very prominent. The presence of oxalate crystals and medullary rays were very conspicuous in *X. maffafa* accessions than in *C. esculenta* accessions.

The control sample of NCe 001 had barrel shaped epidermal cells, no oxalate crystals and 50 vascular bundles. Convex shaped epidermal cells were induced with 2.5, 5 and 7.5mg/kg of sodium azide and with 2.5, 5 and 7.5kg of potassium chromate treatments. Oxalate crystals were also observed with 7.5kg/kg of sodium azide treatment. 30 to 53 vascular bundles were counted in sodium azide treatments while 32 to 44 vascular bundles were observed in potassium chromate treatments.

The control sample of NCe 002 had barrel shaped epidermis, oxalate crystals and 40 shaped vascular tissues. The treatments did not alter the shape of the epidermis but there were no oxalate crystals in all concentrations of the treatments. A total of 45 to 63 vascular tissues were observed in sodium azide treatments while 32 to 54 vascular tissues were observed in potassium chromate treatments.

The control sample of NCe 003 had barrel shaped epidermal cells, no oxalate crystals and 54 vascular bundles. Convex shaped epidermal cells were observed with 10 mg/kg of sodium azide and with 2.5 and 7.5mg/kg of potassium chromate. The presence of oxalate crystals were observed with 2.5mg/kg of sodium azide and with 2, 5 and 7.5mg/kg of potassium chromate treatments. The treatments decreased the number of vascular bundles; 29 to 42 vascular bundles were observed with sodium azide treatments while 28 to 41 vascular bundles were counted with potassium chromate treatments.

The control sample of NCe 004 had barrel shaped epidermis, oxalate crystals and 38 oval shaped vascular tissues. Convex shaped epidermal cells were observed with 5 and 7.5mg/kg of sodium azide, oxalate crystals were observed to be absent with 10mg/kg of sodium azide and with 5mg/kg of potassium chromate. 5mg/kg of potassium chromate treatment was observed to change the shape of the vascular tissues from oval to elliptical. 30 to 36 vascular tissues were counted with potassium chromate treatments while 21 to 95 vascular tissues were observed with sodium azide treatments.

The control sample of NCe 005 had barrel shaped epidermis, no oxalate crystals and 32 vascular bundles. Convex shaped epidermal cells were observed with 2.5 and 7.5mg/kg of sodium azide and with 7.5mg/kg of potassium chromate. Oxalate crystals were also induced with 5, 7.5 and 10mg/kg of sodium azide and with 2.5 and 7.5mg/kg of potassium chromate treatments. Conjoined vascular bundle was observed with 10mg/kg of sodium azide treatment; 35 to 45 vascular bundles were counted for sodium azide treatments while 31 to 50 vascular bundles were observed for potassium chromate treatments.

Control sample of NXs 001 had convex shaped epidermal cells, heavy presence of oxalate crystals and 46 vascular bundles but no medullary ribs. Oxalate crystals were observed to be absent with 2.5 and 10mg/kg of sodium azide treatments also, medullary ribs were observed with 5 and 7.5mg/kg of sodium azide and with 5mg/kg of potassium chromate treatments. 33 to 52 vascular bundles were observed with sodium azide treatments while 17 to 41 vascular bundles were seen with potassium chromate treatments.

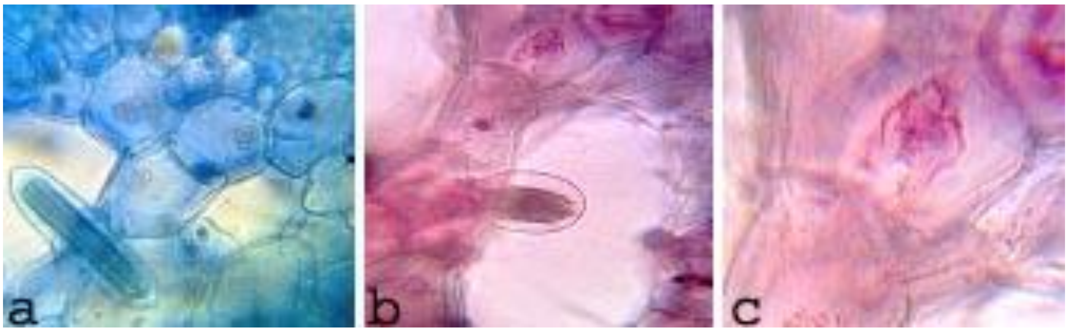

Plate 3: Types of oxalate crystals: a) Raphide idioblasts b)styloid and c) Druse.

Control sample of NXs 002 had convex shaped epidermis, medullary ribs, oxalate crystals and 34 vascular bundles. Treatment with 5mg/kg of potassium chromate induced the absence of medullary ribs. Conjoined vascular bundle was observed with 10mg/kg of potassium chromate treatment; 16 to 89 vascular bundles were counted with potassium chromate treatments while 40 to 52 vascular bundles were counted with sodium azide treatments.

The control sample of NXs 003 had convex shaped epidermal cells, medullary ribs, conjoined vascular bundles, no oxalate crystals and 51 vascular bundles. Oxalate crystals were observed with 2.5, 5 and 7.5mg/kg of sodium azide treatments and with 10mg/kg of potassium chromate treatment. Medullary ribs

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were also observed to be absent with 2.5mg/kg of sodium azide treatment. Conjoined vascular bundles was absent in all the treatment concentrations except for the treatment with 5mg/kg of sodium azide; 50 to 70 vascular bundles were counted with sodium azide treatments while 45 to 66 vascular bundles were observed with potassium chromate treatments.

Treatments with these two oilfield chemicals induced thicker cuticles (Plate 1). The difference between the control and the treated accessions can clearly be distinguished by the number of vascular tissues. The number of vascular tissues in the petiole was higher than the number of vascular tissues in the mid rib (Table 1). It was observed that while the treatments increased the mean number of vascular bundles in some accessions (NCe 002, NCe 004, NCe 005, NXs 002 and NXs 003), the treatments also decreased the mean number of vascular bundles in some other accessions (NCe 001, NCe 003 and NXs 001) in relation to their controls. Comparison between the two chemical treatments also showed that sodium azide treatments caused the increase in the mean number of vascular bundles than potassium chromate treatments (Figure 2). Moreover, statistical analysis showed that a significant difference (at 5 %) between the petiole and the mid rib in the number of vascular bundles, The difference in the number of vascular bundles between accessions and between various treatments were also significant at 5 %.

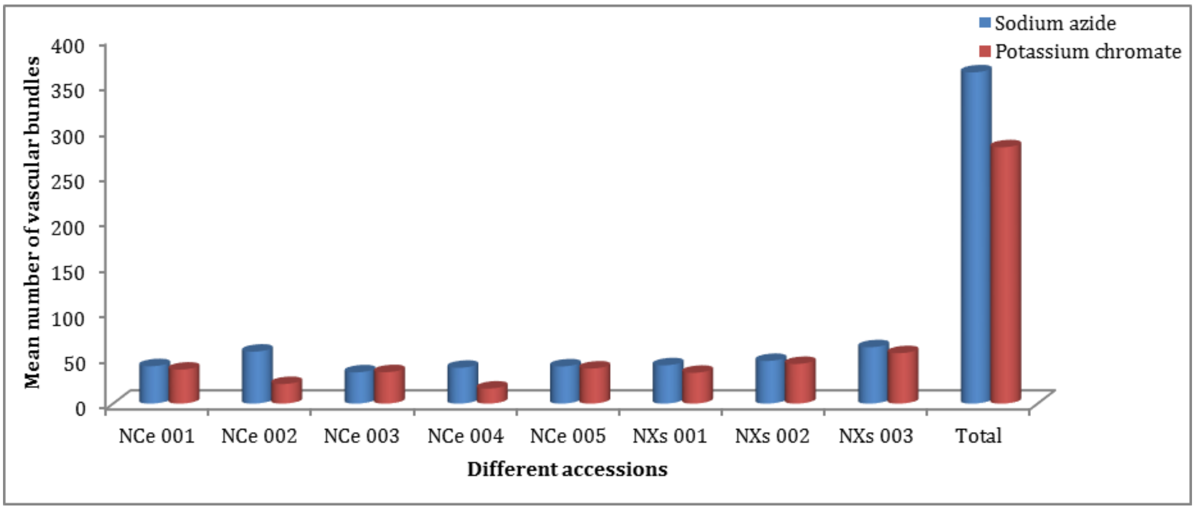

Figure 2: Effects of sodium azide and potassium chromate treatments on the mean number of vascular bundles in the petiole

DISCUSSION

Anatomical features are known to be very reliable in determining the effects of pollutants in plants, as they are rarely affected by environmental factors (Stace, 1980). The ability of plants to adapt to extreme environmental conditions results in their specific morpho-anatomical characteristics (Carlquist, 1961, Stevovic *et al*., 2010). The effects of these chemicals were observed to change the barrel shaped surface of epidermal cells of *C. esculenta* accessions to convex shape. Luis *et al*., (2010), suggested that the convex shaped epidermal cell walls increases leaf's efficiency to capture light energy thereby facilitating photosynthetic and growth abilities of plants.

The epidermal cells of the control accessions have thin cuticles while that of the treated plants have thicker cuticle layers. Akin and Robinson (1982), affirmed that increased thickness of the cuticle aid in building plant's defensive mechanisms against herbivores and pathogenic attacks.

Calcium oxalate is a secondary metabolite, which has been reported widely in plants (Osuji and Ndukwu, 2005; Osuji, 2013). The frequency of occurrence, quantity and distribution of oxalates of calcium are important taxonomic characters, which have been clearly used to delimit cultivars as well as characterize plant germplasm (Osuji *et al*., 1997 and Osuji, 2006). The occurrence and importance of oxalate crystals have been reported in different organs of *Colocasia esculenta* and *Xanthosoma maffafa*; their importance includes being used as storage and waste products in plants, and helps plants ward off herbivores (Osuji, 2013). In this study, the presence of the three types of oxalate crystals (raphides, styloids and druses) were observed, this complements the findings of Osuji (2013) that reported the presence of raphide bundles and intra-amylar crystals. Raphides are bundles of narrow, elongated needle-shaped (a) crystals usually found in crystal idioblasts in parenchymatous tissues; they are mostly grooved in Araceae (Osuji, 2013). Styloids ('pseudoraphides') are thicker than raphides, they are elongated and may have pointed or squared ends (b). Druses are crystal conglomerates possibly formed around a nucleation site (c); they are multiple crystals that are also associated with para-crystalline bodies in their early developmental stages (Prychid and Rudall, 1999). In the mid ribs, it was observed that the treatments induced oxalate crystals in accessions NCe 001 and NCe 004 hence, helping to build their defensive mechanisms against herbivore attacks. But in NCe 002, there were no oxalate crystals even in the treated accession. In the same vein, the petiole of NCe 002 also experienced total absence of oxalate crystals with the treatments; making this accession defenceless against attack herbivore and pathogenic attacks.

The most pronounced anatomical difference in this study is the number of vascular bundles between the control and the treated accessions. The treatments increased the number of vascular bundles in some accessions while reducing their number in some accessions. This correlates the assertion that each accession reacts in a unique way to different environmental conditions (Osuji and Nwala, 2015). The petiole of NCe 003 witnessed reduced number of vascular tissues with both treatments when compared with the control. This indicates that the food and water distribution potentials of this accession was slowed down by these chemicals hence, reducing its metabolic activities. Sodium azide treatments increased the mean number of vascular bundles in both the mid ribs and the petioles when compared to potassium chromate treatments. Vascular tissues are conductors of food and water transport in plants; their increased presence accelerates both growth and photosynthetic activities in plants. This trend explains the reason why some authors have called for the use of sodium azide in crop breeding programs (Al-Qurainy and Khan, 2009; Warghat *et al*. 2011; Eze and Dambo, 2015). Elliptical vascular bundle observed in NCe 004 treated with 5mg/kg of potassium chromate indicates that this chemical induced stress to the accession. Alves and Angyalossy-Alfonso (2000), stated that changes to the size, arrangement and shape of vascular elements are related to the maintenance of the transport capability when the plant is subject to some kind of stress. This connotes the reason why this particular accession reacted so poorly to the treatments as it was observed that the treatments decreased the mean number of vascular bundles in its mid rib. Conjoined vascular bundles have been described as an abnormality and ironically, as being of taxonomic value. The presence of this type of vascular bundle in plant species has to be further investigated to ascertain its economic importance and roles in aiding plants withstand environmental stress.

In conclusion, the introduction of these oilfield chemicals caused anatomical variations in *C. esculenta* and *X. maffafa* accessions; these variations have been seen as an adaptation strategy by these plant species to survive in a polluted environment. From the present study, it is apparent that the cuticles, epidermal cells, oxalate crystals and vascular tissues were highly influenced by these chemicals compared to other tissues. The vascular tissues were very sensitive to these pollutants and statistical analysis collaborated the same. The pollutant, sodium azide also proved to be very potent in inducing profuse vascular tissues in these accessions; increased number of vascular tissues in a plant means that there will be an accelerated growth. This could be the reason why some scholars have advocated the use of this chemical in plant breeding programs. However, further genetic studies have to be carried out to determine the efficacy of this chemical in improving or deteriorating the crop plants and the environment.

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