

# **Original Research Article**

## **Genotoxic and Cytotoxicity Activities of Leaf Extract of *Setariamegaphylla***

### ABSTRACT

*Setariamegaphylla* a medicinal plant, used in ethnomedicine for the treatment of malaria, diabetes and inflammatory diseases was investigated for cytotoxic and genotoxic effects on the root meristem cells of *Allium cepa*. Onion bulbs were exposed to 2.5 mg/ml, 5mg/ml, and 10 mg/ml concentrations of the leaf extract for macroscopic and microscopic analysis. Tap water was used as a negative control and Methotrexate (0.1 mg/ml) as a positive control. There was statistically significant ( $P < .05$ ) inhibition of root growth depending on concentration by the extract when compared with the negative control group. All the tested concentrations of the extract were observed to have cytotoxic effects on cell division in *A. cepa*. The extract- induced chromosomal aberrations and micronuclei (MNC) formations in *A. cepa* root tip cells were significant ( $P < .05$ ) when compared with control group. The extract treatment further induced cell death, ghost cells, cells membrane damage, and binucleated cells. These results suggest that *Setariamegaphylla* leaf extract possess cytotoxic and genotoxic effects on *A. cepa* which is as a results of its phytochemical constituents.

**Keywords:** *Setariamegaphylla*; genotoxicity, cytotoxicity, *Allium cepa* test

### 1. INTRODUCTION

*Setariamegaphylla* (Steud) Dur & Schinz (Poaceae), a perennial grass found in tropical and subtropical areas of the World<sup>1</sup> is traditionally used for the treatment of malaria and diabetes among others<sup>2</sup>. Preliminary reports of antiplasmodial activity on the leaf have been published<sup>2; 3</sup>. The leaf extract also possess antidiabetic and hypoglycaemic [4,5], anti-inflammatory, analgesic [6], cytotoxic, immunomodulatory and antileishmanial [7], antidepressant [8], inhibitory effect on  $\alpha$ -amylase and  $\alpha$ -glucosidase [9] activities. Phytochemical analysis of the leaf extract shows that it contains such as flavonoid, carbohydrate, terpenes, saponins, tannins, anthraquinones, cardiac glycosides (Z,Z,Z)-8,11,14-eicosatrienoic acid, phthalic acid, diisooctyl ester, vitamin E,  $\gamma$ -elemene, urs-12-ene, bicyclogermacrene,  $\alpha$ -muurolene, germacrene-A, and guaialol have been reported [6,7]. 1-triacontanal, 1-triacontanol, 1-dotriacontanol, 1-triacontyl cerotate, and stigmasterol have also been isolated from the plant leaves [5]. In this study, genotoxic and cytotoxic potentials of the root extract of *S. megaphylla* on *Allium cepa* test are reported.

### 2. MATERIAL AND METHODS

#### 2.1 Collection and identification of plant material

The leaf of *Setariamegaphylla* was collected from farms in the Uruan area of Akwa Ibom State, Nigeria. The plant was identified by a taxonomist in the Department of Botany and Ecological Studies, University of Uyo, Uyo, Nigeria. A voucher specimen (UUPH. 221 d) of the plant was deposited in the Department of Pharmacognosy and Natural Medicine herbarium at the University of Uyo.

#### 2.2 Extraction

The plant parts (leaves) were washed and air-dried on laboratory table for 2 weeks. The dried materials were pulverized using a pestle and mortar. The powdered material was macerated in 50% ethanol for 72 hours. The liquid ethanol extract obtained by filtration was evaporated to dryness in a

rotary evaporator 40°C. The extract was stored in a refrigerator at 4°C until used for experiment reported in this study.

### 2.3 *Allium cepa* test

Small bulbs of the common onion, *A. cepa*, were procured from Jos, Northern region of Nigeria. Prior to initiating the test, the outer scales of the bulbs and the dry bottom plate were removed without destroying the root primordia using a small sharp knife and collected in a jar of water. The plant extract (20 g) was dissolved in 200 mL of distilled water. Different concentrations of 2.5 mg/mL, 5 mg/mL and 10 mg/mL respectively were prepared from the stock solution. Test concentration of the plants' extract at 2.5 mg/mL, 5 mg/mL, and 10 mg/mL concentrations prepared in 15 mL beakers were arranged in a series of 5 per test concentration and filled up for each concentration. One *A. Cepa* bulb was placed on top of each beaker, with the root primordia downward toward the liquid. Tap water was used as negative control and Methotrexate (0.1mg/mL) was used as positive control. After 24 hours, the test samples were changed in the controls and all test concentrations and photographs of the growing *A. cepa* roots were captured. This continued for 72 hours, after which the roots were counted per beaker in all the tested concentrations and mean root number was calculated. Similarly, the roots' lengths were measured using a metre rule and the mean root length was calculated. These were also done for the control. Several root tips were cut at a length of 10 mm from the bulbs at 8:30 am, and respectively fixed in 3:1 (v/v) ethanol: glacial acetic acid and 1N HCL before putting them in sample bottles and storing in a refrigerator until use.

### 2.4 Microscopy

The root tips were each placed in a test tube with 1N HCL and heated at 50°C for 6 minutes in order to fix and macerated them. Thereafter, the root tips were placed on microscopic slides on a blank background with a forcep and were cut off at terminal tips. Two drops of 2% (w/v) orcein stain was added and mixed with the rootlets properly by knocking and stirring with a stirring spatula.

Then a cover slip was placed at 45° to avoid air bubbles. After that, the cells were squashed by placing a filter paper on the cover slip and pressed slight with a thumb. The cover slip was sealed with a clear finger nail polish and each slide was examined using a Light Microscope at a magnification of x40. Microphotographs were taken to show chromosomal aberrations. The mitotic index and frequency of chromosomal aberration were calculated based on the number of aberrant cells per total cells scored at each concentration of each sample [10]. The mitotic inhibition was determined using the following formula:

$$\text{Mitotic index} = \frac{\text{Number of dividing cells}}{\text{Total number of cells}} \times 100$$

$$\% \text{Aberrant cells} = \frac{\text{Number of Aberrant cells}}{\text{Total number of cells}} \times 100$$

$$\% \text{root growth of control} = \frac{\text{Overall mean root length of test solution}}{\text{Overall mean root length of control}} \times 100$$

The following parameters were used for determination of cytotoxicity and genotoxicity: (i) the mitotic index (MI) was calculated as the ratio between the number of mitotic cells and the total number of cells scored and expressed as percentage and (ii) chromatin aberrations (stickiness, bridges, breaks and polar deviation) were used as endpoints for determination of cytogenetic effects and micronuclei (MNC) were scored in interphase cells per 500 cells.

### 2.5 Statistical Analysis

Data obtained from this work were analyzed statistically using one-way ANOVA followed by Tukey-Kramer multiple comparison test using Instat Graphpad software, (San Diego, USA). Differences between means were considered significant at 5% level of significance i.e.  $P \leq .05$ .

### 3. RESULTS AND DISCUSSION

#### 3.1 Physicochemical Analysis

The effect of *Setaria megaphylla* leaf extract on different physicochemical parameters (root number and root length) of *Allium cepa* root tips are presented in Table 1. These results show that all tested concentrations of *Setaria megaphylla* leaf extracts caused significant inhibition in the growth of roots in comparison to negative control and positive control. The inhibition of root number and root length was greater with increasing concentrations of the extract. The average root length in negative and positive control (methotrexate) groups were  $4.66 \pm 1.26$  and  $0.25 \pm 0.22$  cm respectively. However, average root lengths in 10 mg/mL treatment group decreased significantly compared to that of the negative control; ( $0.34 \pm 0.01$  cm) for *S. megaphylla* (Table 1). Average root lengths in treatment groups were decreased depending on concentration, significantly ( $P < .05$ ) when compared to negative control. The root morphology was nearly normal in the negative control group, but at 2.5 mg/mL of *S. megaphylla* leaf extract treated group, the roots appeared slightly brownish and at 5 and 10 mg/mL of *S. megaphylla* leaf extract (Table 1).

**Table 1. Cytotoxicity of *Setaria megaphylla* leaf extract on growing roots of onion (*Allium cepa*)**

Treatment group	Concentration of extract (mg/mL)	Average root Number $\pm$ S.D	Average root length (cm) $\pm$ S.D
Negative control	Tap water	$34.10 \pm 4.62$	$4.66 \pm 1.26$
Methotrexate	0.1	$8.16 \pm 3.28^a$	$0.25 \pm 0.22^a$
<i>Setaria megaphylla</i>	2.5	$13.60 \pm 1.86^a$	$3.24 \pm 0.30^a$
	5.0	$24.40 \pm 4.50$	$1.42 \pm 0.12^a$
	10.0	$13.20 \pm 1.80^a$	$0.34 \pm 0.01^a$

Values are expressed as mean  $\pm$  SEM (n=5). Significant at  $P < .05$  when compared to negative control

#### 3.2 Cytogenetic Analysis

Table 2 shows the effect of *Setaria megaphylla* leaf extracts on cytogenetic parameters of *Allium cepa* roots. Cytogenetic analysis performed showed that the extract caused concentration-dependent and significant ( $P < .05$ ) decreases in the mitotic index when compared to that of negative control. The leaf extract of *S. megaphylla* at 10 mg/mL had mitotic index of  $24.20 \pm 3.51$  as compared to  $57.60 \pm 12.34$  recorded in the negative control group (Table 2).

Cytogenetic alterations caused by the leaf extract are shown in Table 3. Chromosome and cytological alterations were observed in negative control, methotrexate, *Setaria megaphylla* leaf extract-treated groups as depicted in Table 3. An analysis of chromosome aberrations observed showed that most of the fragments detected in the different treatments were of chromosome type especially in the highest concentration of the extract (Table 3) (Figure 1(a)). The observation of chromosome breaks showed the clastogenic effect of extract. This was significant ( $P < .05$ ) when compared to negative control group. Sticky metaphase and polar deviations (wrong directions of chromosome movement) were also observed (Figures 1(b)) in the extract-treated groups but were more frequent in the group treated with the highest concentration of extract (10 mg/mL). Sticky metaphase were also observed in the extract-treated groups. These abnormalities were observed to increase with increasing concentrations of the extract. A concentration-dependent and statistically significant ( $P < .05$ ) increase in total aberrant cells (aberrant cells include chromosome breaks, stickiness and polar deviation) as compared with the negative control (Table 3) was observed with the leaf extract with the highest concentrations exerting the highest effect and higher frequencies of aberrations. Genotoxic activity of the extract were further demonstrated by the induction of micronuclei in the root tip meristem cells of

*A. cepa*. Micronucleus formation in 500 cells per slide (%MNC value) was not concentration-dependent as the groups treated with methotrexate and 10 mg/mL of *S. megaphylla* had highest numbers of cells with micronuclei in the test compared to negative control, which were statistically significant ( $P < .05$ ) (Figure (c)). The increase also occurred in the positive control. In *Allium* test, a strong toxic effect of extract was observed and supported by great occurrence of sticky metaphases, leading to cellular death (mitotic index decrease). In addition, cells with membrane damage (Figure 1(d)), binucleated cells (Figure 1(c)), and nucleus damage (Figures 1(d)) were found in various frequencies. Also, apoptotic cells (Figure 1(d)) were detected in the extract-treated groups.

**Table 2. Dividing and total cells counted under microscopic observations and mitotic values in control and treatment concentrations**

Treatment group	Concentration of extract (mg/mL)	Total Number of cells	Dividing cells	M.I (%)± S.E
Negative control	Tap water	500	288	57.60±12.34
Methotrexate	0.1	500	15	3.00±0.68 <sup>a</sup>
<i>Setaria megaphylla</i>	2.5	500	202	40.40±4.56
	5.0	500	151	32.20±4.95 <sup>a</sup>
	10.0	500	121	24.2±3.51 <sup>a</sup>

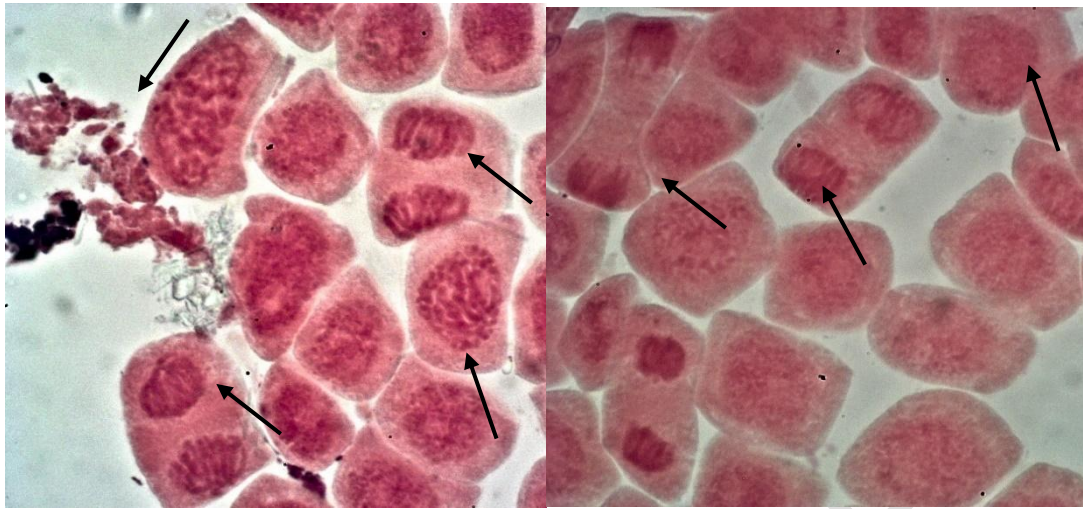
Values are expressed as mean±SEM (n=5). Significant at  $P < .05$  when compared to negative control

**Table 3. Chromosomal and mitotic aberrations in the root meristematic cells of *Allium cepa* after treatment of extract of *Setaria megaphylla***

Treatment group	Concentration of extract (mg/mL)	Chromosome breaks (%)±S.E	Stickiness (%) ±S.E	Polar deviation (%)±S.E	Aberrant cells (%)±S.E	MNC (%)± S.E
Negative control	Tap water	-	0.11±0.08	0.31±0.04	1.05±0.56	-
Methotrexate	0.10	2.34±1.23 <sup>a</sup>	21.34±5.38 <sup>a</sup>	10.55±2.28 <sup>a</sup>	45.13±4.22 <sup>a</sup>	2.28±0.86 <sup>a</sup>
<i>Setaria megaphylla</i>	2.5	3.45±0.22 <sup>a</sup>	18.15±1.04 <sup>a</sup>	1.88±2.68 <sup>a</sup>	30.56±4.57 <sup>a</sup>	1.34±0.16 <sup>a</sup>
	5.0	2.85±0.56 <sup>a</sup>	25.18±5.57 <sup>a</sup>	3.44±0.24 <sup>a</sup>	36.41±5.96 <sup>a</sup>	1.02±0.38 <sup>a</sup>
	10.0	3.26±1.06 <sup>a</sup>	52.46±6.78 <sup>a</sup>	2.53±0.28 <sup>a</sup>	62.14±6.94	2.66±1.04 <sup>a</sup>

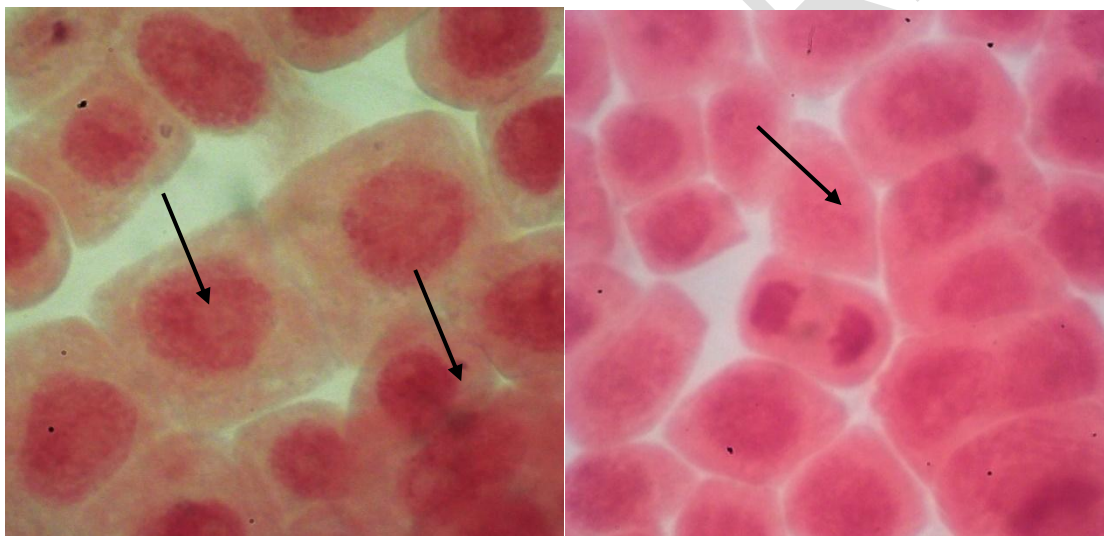
Values are expressed as mean±SEM (n=5). Significant at  $P < .05$  when compared to negative control

### 3.3 Light Microscopy



(a)

(b)



(c)

(d)

**Fig.1.**Photomicrography showing the mitotic and chromosomal aberrations after the *Setaria megaphylla* extract treatments in *Allium cepa* root tip meristem cells visualized with light microscopy at magnification X40. **(a)** visible fragments and polar deviation **(b)** polar deviations and stickiness at metaphase **(c)** micronucleus **(d)** ghost cells.

### Discussion

In this study, toxic effect of *Setaria megaphylla* leaf extract was evaluated by analyzing root growth and root morphology of *Allium cepa*. Varying concentrations of the extract were observed to cause inhibition of root growth and these were statistically significant when compared to control group. In addition, the extract induced colouration of the root tips *Allium cepa* depending on the concentration. This colouration ranged from light brown to dark brown coloration of the roots. Cyto- and genotoxicity were estimated by observing cytological parameters such as the mitotic index and number of chromosome abnormalities, including chromosome breaks, stickiness, and polar deviations. The mitotic index (MI) of *A. cepa* meristematic cells treated with methotrexate (3.00%) was significantly

decreased when compared to control. Significant inhibition in the onion roots treated with the *S. megaphylla* (40.40%, 32.20% and 24.20%) compared to the negative control were observed (Table 2). The inhibition of root growth was found to be dependent on decrease of mitotic index. The decline of mitotic index below 22% in comparison to negative control can have lethal impact on the organism [11], while a decrease below 50% usually has sublethal effects [12] and is called cytotoxic limit value [13]. Mitotic index measures the proportion of cells in the M-phase of the cell cycle and its inhibition could be interpreted as cellular death or a delay in the cell proliferation kinetics [13]. Reduction in the mitotic activity could be due to inhibition of DNA synthesis or a blocking in the G2 phase of the cell cycle, preventing the cell from entering mitosis [14]. Mitodepressive effects of some herbal extracts, including the ability to block the synthesis of DNA and nucleus proteins, were reported earlier [15,16]. Several other herbal extracts have been reported to inhibit mitosis [17,18,19]. The decreased mitotic index in *A. cepa* roots treated with *S. megaphylla* leaf extract is probably due to either disturbances in the cell cycle or chromatin dysfunction induced by extracts-DNA interactions. The results of this study suggest that the tested extract concentrations have inhibitory, mito-depressive effects on root growth and cell division of *A. cepa* and it can prevent DNA synthesis and the reduction in number of the dividing cells in roots produced by the cytotoxic effects of compounds found in the extract. The observation of sticky metaphase reinforces the hypothesis of the toxic effect of the extract. Metaphases with sticky chromosome, loses their normal appearance, and they are seen with a sticky "surface," causing chromosome agglomeration [20]. Stickiness has been attributed to the effect of pollutants and chemical compounds on the physical-chemical properties of DNA, protein or both, on the formation of complexes with phosphate groups in DNA, on DNA condensation or on formation of inter- and intra chromatid cross links [21]. Chromosomal aberrations (CA) are changes in chromosome structure resulting from a break or exchange of chromosomal material. Most of the CA observed in cells are lethal, but there are many related aberrations that are viable and that can cause genetic effects, either somatic or inherited [22]. The presence of chromosome fragments, as was the case in this study, is an indication of chromosome breaks, and can be a consequence of anaphase/telophase bridges [23]. The extract under study was found to not only interfere with the cell cycle, but also affect chromatin organization or DNA replication, causing chromosome breaks. Frequencies of total chromosome aberrations increased significantly following exposure to the extracts which indicate clastogenic activity (Table 3). The extract significantly induced the formation of MNC in *A. cepa* root cells at 2.5–10 mg/mL concentrations. However, MNC frequency decreased in *A. cepa* roots treated at the highest concentration of the extracts (10 mg/mL), due to high cytotoxicity. The frequency of cells with micronuclei is a good indicator of the cytogenetic effects of tested chemicals. Micronuclei (MN) often results from the acentric fragments or lagging chromosomes that fail to incorporate into the daughter nuclei during telophase of the mitotic cells and can cause cellular death due to the deletion of primary genes [24,25]. Previous studies have suggested MNC-induced effect of various plant extracts such as *Lavandula stoechas* and *Ecballium elaterium* [17,26], *Azadirachta indica* [27], *Psychotria* species [18].

In this study, membrane damaged cells were observed in groups treated with 5 mg/mL and 10 mg/mL of the extract. These results show that the extract over certain concentrations may cause cytotoxicity and membrane damage. These results further support the cytotoxicity activities reported on *Setaria megaphylla* leaf extracts [7]. Multinucleated and binucleated cells have been observed in extracts treated groups. This is due to the prevention of cytokinesis or cell plate formation. Microtubules have been implicated in cell plate formation and the extracts the process, resulting in inhibition of cytokinesis. Ghost cell is a dead cell in which the outline remains visible, but whose nucleus and cytoplasmic structures are not stainable [26]. Some ghost cells were observed in various frequencies in this study (Figure 2). This could have resulted from the activities of the phytochemical constituents of the extract leading to nucleus damage and prevention of cytoplasmic structures, thus resulting in ghost cells. In addition, the extract also induced DNA damage and cell death and/or apoptosis in various frequencies in this study. In this study, high concentrations (5 mg/ml and 10 mg/ml) of the extract were found to cause the induction of cell death and/or apoptosis. Cell death is a basic biological process of living organism. The cell death is induced by high concentrations of such as toxin, stress, heavy metals, chemicals and others. The results of this study show that the extract of *S. megaphylla* can induce cytogenetic alterations (cytoplasmic shrinkage, nuclear condensation, DNA fragmentation, membrane blebbing, cytoskeleton alterations and appearance of apoptotic bodies) and cell death in root tips of *A. cepa* (Figures 1(a), 1(b), 1(c), and 1(d)), suggesting cytotoxic and genotoxic activities of the extract.

Therefore, proper use of this plant in ethnomedicine is recommended and high doses should be avoided as it can cause cytotoxic and/or genotoxic effects.

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## 4. CONCLUSION

This study revealed that the leaf extract of *Setaria megaphylla* possesses cytotoxic and genotoxic effects, as seen in the effects elicited by all test concentrations of the plant extract on the root number, root length, and root morphology of the *Allium cepa* meristems after exposure. The degree of chromosomal aberrations (based on increasing extract concentration), the inhibition of cellular mitotic processes, and the general abnormalities observed in all root bulbs treated with the extract further indicate cytotoxic potentials of *Setaria megaphylla* leaf not only in experimental plant tissues, but also quite possibly in animal systems as well.

## REFERENCES

1. Van Oudtshoorn FP. Guide to Grasses of South Africa. Briza Publications, Cape Town; 1999.
2. Okokon JE, Ubulom PM, Udokpoh AE. Antiplasmodial activity of *Setariamegaphylla*. *Phytother Res.* 2007;21: 366-368.
3. Okokon JE, Okokon PJ, Sahal D. . In vitro antiplasmodial activity of some medicinal plants from Nigeria. *Int J Herbal Med.* 2017;5(5): 102-109.
4. Okokon JE, Antia BS.. Hypoglycaemic and antidiabetic effect of *Setariamegaphylla* on normal and alloxan induced diabetic Rats. *J Nat Remedy.* 2007;1: 134-138.
5. Okokon JE, Davies K, Lekara J, Iwara K, Thomas P, Li W-W. Antidiabetic and hypolipidemic activities of solvents fractions of *Setariamegaphylla* and its phytochemical characterisation. *Phytomedicine Plus.* 2022;2(2022): 100182.
6. Okokon JE, Antia BS, Ita BN. (Antiinflammatory and antinociceptive effects of ethanolic extract of *Setariamegaphylla* leaves in rodents. *Afr J Biomed Res.* 2006;9: 229-233.
7. Okokon JE, Dar A., Choudhary MI. Immunomodulatory, cytotoxic and antileishmanial activities of *Setariamegaphylla*. *Int J Phytomed.* 2013;4: 155-160.
8. Okokon JE, Otuikor JE, Davies K. Psychopharmacological study on ethanol leaf extract of *Setariamegaphylla*. *Afr. J Pharmacol Ther.* 2016;6(4); 166-172.
9. Okokon JE, Davies K, Lekara J, Iwara K, Kumar H. Effect of solvents leaf fractions of *Setariamegaphylla* on alpha amylase and alpha glucosidase activities in rats. *Adv Pharm J.* 2021;6(4): 111-115.
10. Bakare AA, Mosuro AA, Osibanjo O. Effect of Simulated Leachate on Chromosomes and mitosis in roots of *Allium cepa* L. *J. Environ. Biol.* 2000;21:263–271.
11. Antonsie-wiez D. Analysis of the cell cycle in the root of *Allium cepa* under the influence of *Leda krin*,” *Folia Histochemica et Cytobiologica.* 1990;26:79–96.
12. Panda BB, Sahu UK. Induction of abnormal spindle function and cytokinesis inhibition in mitotic cells of *Allium cepa* by the organophosphorus insecticide fensulfothion,” *Cytobios.* 1985;42(167- 168):147–155.
13. Sharma CB. Plant meristems as monitors of genetic toxicity of environmental chemicals,” *Current Science.* 1983;52: 1000–1002.
14. Sudhakar R, Ninge Gowda KN, Venu G. Mitotic abnormalities induced by silk dyeing industry effluents in the cells of *Allium cepa*,” *Cytologia.* 2001; 66(3):235– 239.
15. Mercykutty VC, Stephen J. Adriamycin induced genetic toxicity as demonstrated by *Allium cepa* test,” *Cytologia.* 1980; 45(4):769–777.
16. Schulze E, Kirschner M. “Microtubule dynamics in interphase cells,” *Journal of Cell Biology.* 1986;102(3):1020–1031.
17. As T, kinelik C, Aslanturk OS. “Cytotoxic and genotoxic effects of *Lavandula stoechas* aqueous extracts,” *Biologia.* 2007; 62(3):292–296.
18. As T, kin C, elik, Aslantu”rk OS. Antimitotic and antigenotoxic effects of *Plantago lanceolata* aqueous extract on *Allium cepa* root tip meristem cells,” *Biologia.* 2006;61(6):693–697.
19. Akinboro A, Bakare AA. Cytotoxic and genotoxic effects of aqueous extracts of five medicinal plants,” *Journal of Ethnopharmacology.* 2007;112(3):470– 475.
20. Babich H, Segall MA. Fox KD. “The *Allium* test— a simple, eukaryote genotoxicity assay,” *American Biology Teacher.* 1997; 59(9):580–583.

21. G"om"urgen, AN. "Cytological effect of the potassium metabisulphite and potassium nitrate food preservative on root tips of *Allium cepa* L.," *Cytologia*. 2005;70(2):119–128.
22. Swierenga SH, Heddle JA, Sigal EA. Recommended protocols based on a survey of current practice in genotoxicity testing laboratories, IV. Chromosome aberration and sister-chromatid exchange in Chinese hamster ovary, V79 Chinese hamster lung and human lymphocyte cultures," *Mutation Research*. 1991;246(2):301–322.
23. Sharma A, Sen S. *Chromosome Botany*, Science, Enfield, NH, 2002; USA.
24. Albertini RJ, Anderson D, Douglas GR. IPCS guidelines for the monitoring of genotoxic effects of carcinogens in humans," *Mutation Research*. 2000;463(2):111–172.
25. Krishna G, Hayashi M. In vivo rodent micronucleus assay: protocol, conduct and data interpretation," *Mutation Research*. 2000;455(1-2):155–166.
26. As TA, kin C, elik, Aslantu"rk OS. Investigation of cytotoxic and genotoxic effects of *Ecballium elaterium* juice based on *Allium* test," *Methods and Findings in Experimental and Clinical Pharmacology*. 2009;31(9):591–596.
27. Soliman MI. Genotoxicity testing of neem plant (*Azadirachta indica* A. Juss.) using the *Allium cepa* chromosome aberration assay," *Journal of Biological Sciences*. 2001;1(11):1021–1027

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