J. Biomol. Toxicol., 1(1), 21-29, 2025
https://doi.org/10.56717/jbt.2025.v01i01.03
eISSN: 0000-0000

Journal of Biomolecular Toxicology

Research Article

Genotoxic and cytotoxic activities of ethanol leaf extract of *Panicum maximum* Jacq (Poaceae) on root meristem of *Allium cepa* bulb

Chinyelu Clementina Osigwe[1*], **Ugonma Florence Uwaeme**[1], **Jude Efiom Okokon**[1,2], and **Kemfon Enomfon**[2]

1. Department of Pharmacology and Toxicology, Faculty of Pharmacy, Madonna University, Elele, Rivers State, Nigeria.
2. Department of Pharmacology and Toxicology, Faculty of Pharmacy, University of Uyo, Uyo, Nigeria.

Abstract

There is a growing interest in the therapeutic potential of natural products and the mounting need to ensure their safety and efficacy. *Panicum maximum* Jacq (Poacace) is one of such medicinal plant used traditionally to treat various diseases in Nigeria. The genotoxic and cytotoxic effects of the leaf extract were investigated using the *Allium cepa* test. The effect of *Panicum maximum* leaf extract on the root meristem cells of *Allium cepa* bulbs was investigated using onion bulbs exposed to varying concentrations of the extract (2.5, 5 and 10 mg/mL) for macroscopic and microscopic analyses. Tap water was used as a negative control and methotrexate (0.1 mg/ml) was used as a positive control. There was a statistically significant ($p < 0.05$) inhibition of root growth depending on the concentration of the extract, compared with the negative control group. All 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) formation in *A. cepa* root tip cells were significant ($p<0.05$) when compared with the control group. The treatment with extract induced further cell death, ghost cells, cell membrane damage, and binucleated cells. These results suggest that the leaf extract of *Panicum maximum* exerts cytotoxic and genotoxic effects on *A. cepa* root meristem cells.

Article Information
Received: 27 July 2025
Revised: 06 September 2025
Accepted: 09 September 2025
Published: 25 September 2025

Academic Editor
Prof. Dr. Raffaele Capasso

Corresponding Author
Prof. Dr. Chinyelu Clementina Osigwe
E-mail: drchinyeluosigwe@gmail.com
Tel: +234-8037169260

Keywords
Panicum maximum, cytotoxic, genotoxic, *Allium cepa*, meristem, apoptosis.

1. Introduction

Panicum maximum Jacq (Poaceae) is a perennial, tuft grass with a short, creeping rhizome regarded as the most valuable fodder plant and is extensively used to make hay. The stems of this robust grass can reach a height of up to 2 – 3 m. Leaf sheaths were found at the bases of the stems and covered in fine hairs. It is a tropical grass that is widely distributed in Africa and other tropical regions of the world and is usually found along roads and in uncultivated farmlands and fields [1]. The people of Southern Nigeria use the leaves ethnomedically in the treatment of various ailments, such as malaria, microbial infections, rheumatism pain, inflammation and diabetes. Some of these ethnomedical claims have been validated scientifically. Antidiabetic [2], antimalarial and analgesic [3], antibacterial [4-6], anti-inflammatory and antipyretic [7], antifungal [8], anticancer, antioxidative burst, antileishmanial [9], antidepressant [10], anticonvulsant [11], alpha amylase and alpha glucosidase inhibitory [12] activities of the leaf extracts have been reported. Phytochemical components such as phytol, pentadecanoic, hexadecanoic, dodecanoic and 8,11,14-eicosatrienoic (Z, Z, Z) acids as well as mono

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution 4.0 International License (CC BY-NC 4.0).

and sequiterpenes, such as terpinen-4-ol, borneol and germanicol have been reported in the leaf extract [9]. Despite its wide use in traditional medicine for the treatment of various diseases, there is a paucity of scientific information on the safety profile of this plant extract and evidence on the genotoxic and cytotoxic potential of *Panicum maximum* leaf extract. Thus, we investigated the genotoxic and cytotoxic activities of ethanol leaf extract of *Panicum maximum* on the root meristem cells of *Alium cepa* bulbs.

2. Materials and methods

2.1. Plants collection

The fresh leaves of *Panicum maximum* were collected in May, 2023 at Farmland in Uyo, Uyo LGA, Akwa Ibom State, Nigeria. The plant was identified and authenticated as *Panicum maximum* by a taxonomist, Prof. Margaret Bassey, in the Department of Botany and Ecological Studies, University of Uyo, Uyo. Nigeria. The herbarium specimens were deposited at the Faculty of Pharmacy Herbarium (FPH 76c), University of Uyo, Nigeria. The bulbs of *A. cepa*, which were procured from the Itam market, in Itu LGA of Akwa Ibom State, were equally identified and authenticated, as reported above.

2.2. Extraction

The leaves of *P. maximum* were washed and air-dried on a laboratory table for 2 weeks. The dried leaves were pulverized using a mortar and pestle. Powdered leaves (1 kg) were macerated in 95% ethanol for 72 h with intermittent shaking. The liquid ethanol extract obtained by filtration was evaporated to dryness in a water bath at 60 ^{o}C. The extract (yield-12.6%) was stored in a refrigerator at 4 ^{o}C until used for the experiment reported in this study.

2.3. Allium cepa test

2.3.1. Root growth inhibition assay

The methods earlier described by Komolafe [13] and Ikechukwu [14] were used in this experiment. Small onion bulbs (*A. cepa)* were processed for the experiment by scarifying the bulbs of the dry scales and bottom base without destroying the root primordia, using a small sharp knife. Stock solution of the extract was prepared by dissolving 20 g of extract in distilled water (200 mL). Various working concentrations of the extract (2.5, 5 and 10 mg/mL) were prepared from the stock solutions. The test concentrations of the extract (2.5, 5, and 10 mg/mL) prepared in 50 mL beakers were arranged in a series of 5 per test 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 a negative control and methotrexate (0.1 mg/mL) was used as a positive control. After 24 h, the test samples were changed to the control and all the test concentrations. This was continued for 72 h, after which the roots were counted per beaker at all the tested concentrations and the mean root number was calculated. Similarly, the root lengths were measured using a metre rule and the mean root length was calculated. These were also done for the control groups. Several root tips were cut at a length of 10 mm from the bulbs at 8:30 am, and fixed in 3:1 (v/v) ethanol: glacial acetic acid for 24 h according to Ikechukwu *et al.* [14] before putting them in sample bottles and stored in a refrigerator until use.

2.3.2. Microscopy

The root tips were placed in a test tube with 1N HCL and heated at 50 ^{o}C for 6 min to hydrolyze and macerate them. Roots were then washed with distilled water. Thereafter, the root tips were placed on microscopic slides on a blank background with forceps and were cut off at terminal tips followed by the addition of two drops of 2% orcein solution and allowed to stand for 2 min to stain properly. Two additional drops of 2% (w/v) orcein stain were added and mixed with the rootlets by knocking and stirring with a stirring spatula. Then a cover slip was placed at 45º to avoid air bubbles. Excess stain was removed with tissue paper by pressing slightly down with the thumb. After that, the cells were squashed by placing a filter paper on a coverslip and pressed lightly with a thumb. Five slides were prepared for each concentration according to Ikechukwu et al. [14]. The cover slip was sealed with a clear fingernail polish and each slide was examined under a light microscope at a magnification of x 40. Microphotographs were obtained to detect chromosomal aberrations. The mitotic index and frequency of chromosomal aberration were calculated based on the number of aberrant cells per total cells counted at each concentration of the test extract [15, 16]. Mitotic

https://doi.org/10.56717/jbt.2025.v01i01.03

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

Treatment group	Concentration of extract (mg/mL)	Average root Number ± S.D	Average root length (cm) ± S.D
Negative control	Tap water	26.40±3.82	4.82±0.12
Methotrexate	0.1	2.10±0.02[a]	0.10±0.01[a]
	2.5	25.4±3.68[a]	3.56±0.29[a]
Panicum maximum	5.0	24.4±4.04[a]	3.12±0.14[a]
	10.0	17.80±3.55[a]	1.96±0.26[a]

Values are expressed as mean ± SEM (n=5). Significant at $p < 0.05$ when compared to negative control.

inhibition was determined using the following formula:

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

The following indices were considered for evaluation 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, expressed as a percentage and (ii) chromatin aberrations (stickiness, bridges, breaks and polar deviation) were used as endpoints for assessment of cytogenetic effects and micronuclei (MNC) were scored in interphase cells per 500 cells.

2.4. Statistical analysis

Data obtained from this study were analyzed statistically using one –way ANOVA followed by Tukey-Kramer multiple comparison tests using the Instat Graphpad software, (San Diego, USA). Differences between the means were considered significant at the 5% level of significance i.e. $p < 0.05$.

3. Results and discussion

3.1. Physicochemical characterization

The effects of *Panicum maximum* leaf extract on physicochemical parameters (root number and root length) are presented in Table 1. This result shows that all tested concentrations of *Panicum maximum* leaf extract caused significant inhibition of roots' growth compared to the negative and positive control groups. Root number and root length decreased as the leaf extract concentration increased. The mean root lengths in the negative and positive control (methotrexate) groups were 4.2 ± 0.12 and 0.10 ± 0.01 cm respectively. However, mean root length in 10 mg/mL treatment group was observed to have decreased significantly relative to negative control; 1.96 ± 0.26 cm for *Panicum maximum* (Table 1). The mean root lengths in the treatment groups decreased, significantly ($p < 0.05$) relative to the negative control. The root morphology and appearance were normal in the negative control group, but root tips treated with 2.5 mg/mL of *Panicum maximum* leaf extract, appeared slightly yellow and at 5 and 10 mg/mL of *Panicum maximum* leaf extract, the roots tips were observed to appear brownish (Table 1).

3.2. Cytogenetic analysis

Table 2 shows the effects of the *Panicum maximum* leaf extract on the cytogenetic parameters of *Alium cepa* roots. Cytogenetic analysis showed that the leaf extract caused a concentration-dependent and significant ($p < 0.05$) decrease in the mitotic index relative to that of the negative control group. The leaf extract of *P. maximum* at 2.5 mg/ml and 10 mg/mL had mitotic index of 14.20 ± 1.33 and 4.80 ± 3.19 as compared to 70.80 ± 3.22 recorded in the negative control group (Table 2).

Cytogenetic alterations caused by the extracts are shown in Table 3. Chromosomal and cytological alterations were observed in the negative control, methotrexate and *Panicum maximum* leaf extract-treated groups, as shown in Table 3. Analysis of chromosome aberrations observed in the study showed that sticky chromosomes, cell walls and nuclear damage as well as polar deviation were detected in the different concentration treatments, especially at the highest concentration (Table 3) (Figs. 1A and 1B). This difference was significant ($p < 0.05$) when compared to the negative control group. Fragmentation or clastogenic breaks of chromosomes, chromosome bridges and laggards were also observed at high concentrations (5 and 10 mg/mL) of the leaf extract (Table 3 and Fig. 1C). Apoptotic bodies,

https://doi.org/10.56717/jbt.2025.v01i01.03

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	354	70.80±3.22
Methotrexate	0.1	500	14	2.80±0.10[a]
	2.5	500	71	14.20±1.33[a]
Panicum maximum	5.0	500	53	10.60±2.14[a]
	10.0	500	24	4.80±3.19[a]

Values are expressed as mean ± SEM (n=5). Significant at $p < 0.05$ when compared to negative control.

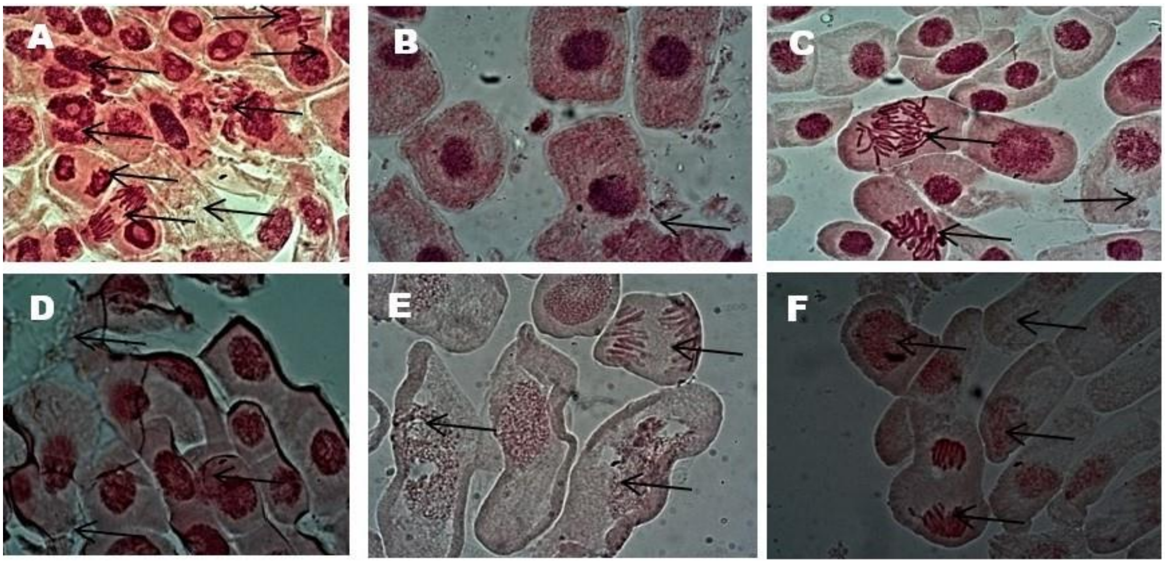

Figure 1. Photomicrograph showing the mitotic and chromosomal aberrations of *Allium cepa* root meristem cells after *Panicum maximum* leaf extract treatments under light microscope X40 magnification. Arrows indicate (A) fragmented chromosomes, apoptotic bodies, polar deviation, sticky chromosomes ,cell wall and nuclear damage (B)cell wall and nuclear damage (C) sticky chromosome, bridge, laggard, cell wall damage (D) cell wall damage and binucleated cell (E) polar deviation, membrane and nuclear damage (F) dead cell, cell wall and nuclear damage, sticky chromosome, polar deviation.

dead cells and binucleated cells were also observed (Figs. 1D and 1E) in the extract-treated groups. It was generally observed that these abnormalities increased with increasing concentrations of the extracts. A concentration-dependent and statistically significant ($p < 0.05$) increase in total aberrant cells (aberrant cells include bridge, laggard and stickiness), compared with the negative control was observed (Table 3). However, the methotrexate-treated group (positive control) showed the highest number of aberrant cells (Table 3). Genotoxic activities of the extract were further demonstrated by the induction of micronuclei in the root tip meristem cells of *A. cepa,* which was not concentration-dependent as the groups treated with methotrexate and 2.5 mg/mL of *Panicum maximum* had a higher number of cells with micronuclei in the experiment, compared to the negative control, which was statistically significant ($p < 0.05$) (Fig. 1(A)). In addition, cells with membrane and nucleus damages (Fig. 1F) were observed at various frequencies. Also, apoptotic cells (Fig. 1E) were detected in the group treated with the leaf extract.

In this study, the toxic effects of *Panicum maximum* leaf extract were assessed by evaluating the growth and morphology of the roots of onion bulb. The root growth was inhibited by various concentrations of the extract relative to the control group, as observed in this study. The root growth inhibition assay is considered a standard model for the assessment of cytotoxic and genotoxic potentials of various

https://doi.org/10.56717/jbt.2025.v01i01.03

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

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	3.23±1.38[a]	34.12±2.38[a]	15.23±2.34[a]	51.12±3.42[a]	3.12±0.56[a]
Panicum maximum	2.5	-	16.38±1.26[a]	-	28.29±3.27[a]	1.04±0.22[a]
	5.0	0.14±0.08[a]	22.48±6.32[a]	1.25±0.69[a]	34.48±3.81[a]	0.45±0.08[a]
	10.0	0.82±0.02[a]	32.02±4.25[a]	2.74±0.56[a]	40.35±4.18	0.64±0.33[a]

Values are expressed as mean ± SEM (n=5). Significant at $p < 0.05$ when compared to negative control.

compounds, including phytoconstituents of medicinal plants [17]. The inhibition of root growth as observed in this study could have resulted from the growth inhibitory activities of some allelochemicals in the extract as well as the prevention of cell division processes prominent at the root tip of *A. cepa* exposed to different concentrations of the extract [18]. This observation was in agreement with the observations of Akpan *et al.* [19] on the growth inhibitory effect of extracts of *Zea mays* husk and *Saccharum officinarum* leaves on *A. cepa* roots.

Cyto- and genotoxicity were also determined by assessing 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 the extract was significantly decreased relative to control. The inhibition of root growth increased with a decrease in mitotic index. The reduction of mitotic index below 22% in comparison to the negative control can have a lethal impact on the organism [20, 21], while a decrease below 50% usually has sub-lethal effects [22, 23], which is called the cytotoxic limit value [24]. Mitotic index measures the proportion of cells in the M phase of the cell cycle and its inhibition can be interpreted as cellular death or a delay in cell proliferation kinetics [25]. The reduction in mitotic activity could be due to inhibition of DNA synthesis or blocking in the G2 phase of the cell cycle, preventing the cell from entering mitosis [26]. The mito-depressive effects of some herbal extracts, including the ability to block the synthesis of DNA and nucleus proteins, have been reported earlier [27, 28]. Several other herbal extracts have been reported to inhibit mitosis [14, 29, 30]. The decreased mitotic index in *A. cepa* roots treated with *Panicum maximum* leaf extract was probably due to either disturbance in the cell cycle or chromatin dysfunction induced by extract DNA interactions. The results suggest that the tested extract concentrations have inhibitory and mito-depressive effects on root growth and cell division in *A. cepa.* These findings also indicate that the extract possesses the potential to prevent DNA synthesis and reduce the number of dividing cells in roots due to the cytotoxic activities of its phytoconstituents.

Chromosomal aberrations (CA) are changes in chromosomal structure resulting from a break or exchange of chromosomal material. Most CA observed in cells are lethal, but there are many related aberrations that are viable and can cause genetic effects, either somatic or inherited [31]. Various chromosomal aberrations such as stickiness, bridge formation, fragmented chromosomes, laggards and polar deviations were observed in the present study. These aberrations might have resulted from the effect of the extract on spindle formation processes, resulting in cell division disturbances. Chromosome bridges indicate clastogenic effects due to chromosome breaks, and laggard chromosomes which, can result in lethal effects [32]. The presence of stickiness in metaphase cells and bridges might have resulted from improper folding of chromosome fibers, which connect the chromatids by means of subchromatid bridges. Sticky chromosomes have a highly toxic, irreversible effect and probably leading to cell death. Stickiness has been attributed to the effect of pollutants and chemical compounds on the physicochemical properties of DNA, proteins or both, on the formation of complexes with phosphate groups

https://doi.org/10.56717/jbt.2025.v01i01.03

in DNA, DNA condensation or the formation of inter- and intra-chromatid cross links [33, 34]. The observation of sticky metaphase supported the toxic effects of the extract. The bridges observed in this study might have been caused by the breakage and fusion of chromatids and subchromatids [17]. The presence of chromosome fragments is an indication of chromosome breaks, and can be a consequence of anaphase/telophase bridges [35].

The frequencies of total chromosome aberrations increased significantly following exposure to the extract indicating clastogenic activity. The obstruction of different phases of cell division and disorganisation of chromosom arrangement at different stages of cell division may be responsible for the increased chromosomal aberrations. These aberrations might have resulted from the activities of the genotoxic constituents of the extract, such as inhibition of DNA synthesis or spindle formation [36].

Micronuclei were observed in this study, especially at the lowest concentrations. The frequency of cells with micronuclei is a good indicator of the cytogenetic effects of the tested chemicals. Micronuclei (MNC) 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 [37, 38]. Previous studies suggesting MNC-induced effect of various plant extracts such as *Azadirachta indica* [39], *Psychotria* species [40], *Lavandula stoechas* and *Ecballium elaterium* [41, 42], *Hippocratea africana* [29], *Setaria megaphylla* [27, 30], *Heinsia crinata, Lasianthera africana* and *Justicia insularis* [14], *Solanum anomalum* fruit [43], *Croton zambesicus* [44], *Stachytarpheta cayenensis* [45] and *Stigma maydis* [46] have been documented.

In this study, membrane-damage cells were observed in all the treated groups. These results indicated the potential of the extract to exert cytotoxic effects over certain concentrations such as membrane damage. Multinucleated and binucleated cells were observed in extract-treated groups. This is due to the prevention of cytokinesis or cell plate formation. Microtubules have been implicated in cell plate formation by the extract, resulting in inhibition of cytokinesis. Ghost cells are dead cells in which the outline remains visible, but whose nucleus and cytoplasmic structures are not stainable [42, 47]. Some ghost cells were observed at various frequencies in this study, especially in the 10 mg/mL treated groups. This could have resulted from the activities of the phytochemical constituents of the extract leading to nuclear damage and the prevention of cytoplasmic structures. In addition, the extract also induced DNA damage, cell death and/or apoptosis at various frequencies. Cell death is a basic biological process occurring in living organisms. The cell death is induced by high concentrations of toxins, stress, heavy metals, chemicals and others [48]. The findings of this study support earlier reports on the cytotoxic potential of leaf extracts by Okokon et al. [9].

Phytochemical components such as phytol, pentadecanoic, hexadecanoic, dodecanoic, and 8, 11, 14-eicosatrienoic (Z, Z, Z) acids, as well as mono and sequiterpenes such as terpinen-4-ol, borneol and germanicol have been reported on the leaf extract of *Panicum maximum* [9]. The phytochemical constituents of this extract may have been responsible for the observed effects in this study. The terpenes present in this extract may have contributed to the observed cytotoxic and genotoxic activities in this study. It has been reported that terpenes especially monoterpenes extracted from various plant sources have shown high cytotoxic potential [49].

4. Conclusions

The results of this study show that the leaf extract of *Panicum maximum* can induce cytogenetic alterations (cytoplasmic shrinkage, nuclear condensation, DNA fragmentation, membrane blebbing, cytoskeleton alterations and appearance of apoptotic bodies) and cell death in the root tips of *A. cepa*, suggesting cytotoxic and genotoxic activities of the extract. However, proper use of this plant in ethnomedicine is recommended and high doses should be avoided, as it can cause cytotoxic and/or genotoxic effects.

Disclaimer (artificial intelligence)

Author(s) hereby state that no generative AI tools such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators were utilized in the preparation or editing of this manuscript.

https://doi.org/10.56717/jbt.2025.v01i01.03

Authors' contributions

Conceptualization, J.E.O., C.C.O.; methodology, J.E.O.; software, U.F.U.; validation, C.C.O., J.E.O.; formal analysis, C.C.O., J.E.O., U.F.U.; investigation, K.E. resources, C.C.O., U.F.U., J.E.O, K.E.; data curation, K.E.; writing – original draft preparation, J.E.O.; writing – review & editing, C.C.O., U.F.U.; visualization, K.E., U.F.U., C.C.O.; supervision, J.E.O., C.C.O., U.F.U.; project administration, J.E.O.

Acknowledgements

The authors are grateful to the Madonna University, Elele campus and University of Uyo mangements for providing enabling environment for the completion of this work.

Funding

There was no external fund received.

Availability of data and materials

All data will be made available on request according to the journal policy.

Conflicts of interest

The authors declare no conflict of interest.

References

1. Van Oudtshoorn, F.P. Guide to Grasses of South Africa. Briza Publications, Cape Town, 1999.
2. Antia, B.S.; Okokon, J.E.; Umoh, E.E.; Udobang, J.A. Antidiabetic activity of *Panicum maximum*. Int. J. Drug Dev. Res. 2010, 2, 488-492.
3. Okokon, J.E.; Nwafor, P.A.; Andrew, U. Antimalarial and analgesic activities of ethanolic leaf extract of *Panicum maximum*. Asian Pac. J. Trop. Med. 2012, 4, 442–446. https://doi.org/10.1016/S1995-7645(11)60122-3
4. Gothandam, K.M.; Aishwarya, R.; Karthikeyan, S. Preliminary screening of antimicrobial properties of few medicinal plants. J. Phytol. 2010, 2, 01–06.
5. Doss, A.; Parivuguna, V.; Vijayasanthi, M.; Sruthi, S. Antibacterial evaluation and phytochemical analysis of certain medicinal plants, Western Ghats, Coimbatore. J. Res. Biol. 2011a, 1, 24-29.
6. Doss, A.; Vijayasanthi, M.; Parivuguna, V.; Anand, S.P. Evaluation of antibacterial properties of ethanol and flavonoids from *Mimosa pudica* linn. and *Panicum maximum* Jacq. Plant Sci. Feed. 2011b, 1, 39–44.
7. Okokon, J.E.; Udoh, A.E.; Udo, N.M.; Frank, S.G. Antiinflammatory and antipyretic activities of *Panicum maximum*. Afr. J. Biomed. Res. 2011, 14, 125-130.
8. Kanife, U.C.; Odesanmi, O.S.; Doherty, V.F. Phytochemical composition and antifungal properties of leaf, stem and florets of *Panicum maximum* Jacq. (Poaceae). Int. J. Biol. 2012, 4, 64–96. https://doi.org/10.5539/ijb.v4n3p64
9. Okokon, J.E.; Okokon, P.J.; Dar, A.; Choudhary, M.I.; Kasif, M.; Asif, M.; Mudassir, A.; Izhar, A. Immunomodulatory, anticancer and antileishmanial activities of *Panicum maximum*. Int. J. Phytother. 2014, 4, 87-92.
10. Okokon, J.E.; Obot, J.; Amazu, L.U.; Nelson, E. Antidepressant activity of ethanol leaf extract of *Panicum maximum*. Afr. J. Pharmacol. Thera. 2018, 7, 21 -26.
11. Iyanyi, U.L.; Oparah, I.; Okokon, J.E. Evaluation of the anticonvulsant activity of ethanol leaf extract of *Panicum maximum* in pentylene tetrazol and strychnine-induced seizure in mice. J. Curr. Biomed. Res. 2023, 3, 1096-1105. https://doi.org/10.54117/jcbr.v3i4.4
12. Okokon, J.E.; Nwokafor, I.; Ebong, N.O. In vivo inhibitory effect of *Panicum maximum* root extract on alpha amylase and alpha glucosidase enzymes of rats. J. Curr. Biomed. Res. 2023, 3, 1084-1095. https://doi.org/10.54117/jcbr.v3i4.3
13. Komolafe, I.J.; Dare, C.A.; Ogunsusi, M.; Akinlalu, A.O.; Fakayode, E.A.; Oziegbe, M.; Oyedapo, O.O. Cytotoxic and genotoxic potentials of the extracts and fraction of the leaf of *Datura metel* (Lnn.). Nig. J. Biochem. Mol. Biol. 2022, 37, 32-34.
14. Ikechukwu, E.; Agu, P.; Olumuji, H.; Anagboso, M.O.; Ebong, N.O.; Okokon, J.E. Evaluation of genotoxic and cytotoxic activities of three vegetables (*Heinsia Crinata, Justicia insularis a*nd *Lasianthera africana*) using *Allium cepa* test. Asian J. Biochem., Gene. Mol. Bio. 2024, 16, 10-20. https://doi.org/10.9734/ajbgmb/2024/ v16i4320
15. Bakare, A.A.; Mosuro, A.A.; Osibanjo, O. Effect of simulated leachate on chromosomes and mitosis in roots of *Allium cepa* L. J. Environ. Biol. 2000, 21, 263–271.
16. Magnus, S.P.; Anagboso, M O.; Johnny, I.I.; Ise, U.P.; Okokon, J.E. Evaluation of genotoxic and cytotoxic activities of leaf and seed extracts of *Telfairia occidentalis*. J. Complement. Alter. Med. Res. 2024, 25, 7-16. https://doi.org/10.9734/jocamr/2024/v25i3527
17. Dragoeva, A.P.; Koleva, V.P.; Nanova, Z.D.; Georgiev, B.P. Allelopathic effects of *Adonis vernalis* l.: root growth inhibition and cytogenetic alterations. J. Agric. Chem. Environ. 2015, 4, 48-55. https://doi.org/10.4236/jacen.2015.42005
18. Salam, A.; Kato-Noguchi, H. Evaluation of allelopathic potential of neem (*Azadirachta indica*. A. Juss) against seed germination and seedling growth of different test plant species. Int. J. Sustain. Agric. 2010, 2, 20-25.

19. Akpan, E.E.; Johnny, I.; Anagboso, M. O.; Ebong, O.O.; Okokon, J.E. Genotoxic and cytotoxic potentials of cornhusk extracts of *Zea mays* and leaf extract of *Saccharum officinarum.* Biol. Med. Nat. Prod. Chem. 2024, 13, 531-540. https://doi.org/10.14421/biomedich.2024.132.485-494
20. Antonsie-wiez, D. Analysis of the cell cycle in the root of *Allium cepa* under the influence of Leda krin. Folia Histochem et Cytobiol. 1990, 26, 79–96. https://journals.viamedica.pl/folia_histochemica_et_cytobiologica. https://doi.org/10.5603/fhc
21. Anuva, B.; Sanjib, R. Mitotic index reduction and cytotoxic effects of leaf aqueous extract of *Maesa macrophylla* (Wall.) A. DC. in *Allium cepa* root tip cells. Cytologia. 2022, 87, 81–85. https://doi.org/10.1508/cytologia.87.81
22. Panda, B.B.; Sahu, U.K. Induction of abnormal spindle function and cytokinesis inhibition in mitotic cells of *Allium cepa* by the organophosphorus insecticide fensulfothion. Cytobios. 1985, 42, 147–155.
23. Levine, M.S.; Holland, A.J. The impact of mitotic errors on cell proliferation and tumorigenesis. Genes Dev. 2018, 32, 620-638. https://doi.org/10.1101/gad.314351.118
24. Sharma, C.B.S.R. Plant meristems as monitors of genetic toxicity of environmental chemicals. Curr. Sci. 1983, 52, 1000–1002.
25. Rojas, E.; Herrera, L.A.; Sordo, M. Mitotic index and cell proliferation kinetics for identification of antineoplastic activity. Anti-Cancer Drugs. 1993, 4, 637–640. https://doi.org/10.1097/00001813-199312000-00005
26. Sudhakar, R.; Ninge Gowda, K.N.; Venu, G. Mitotic abnormalities induced by silk dyeing industry effluents in the cells of *Allium cepa*. *Cytologia*. 2001, 66, 235–239. https://doi.org/10.1508/cytologia.66.235
27. Mercykutty, V.C.; Stephen, J. Adriamycin induced genetic toxicity as demonstrated by *Allium cepa* test. Cytologia. 1980, 45, 769–777. https://doi.org/10.1508/cytologia.45.769
28. Schulze, E.; Kirschner, M. Microtubule dynamics in interphase cells. J. cell Biol. 1986, 102, 1020–1031 https://doi.org/10.1083/jcb.102.3.1020
29. Johnny, I.I.; Okokon, J.E.; Ochigbo, E.B.; Udo, I.J.; Adefabi, A.M. Genotoxic and cytotoxicity potentials of *Hippocratea africana.* Asian J. Biochem., Gene. Mol. Bio. 2023, 15, 38-45. https://doi.org/10.9734/ajbgmb/2023/v15i2305
30. Okokon, J.E.; Ochigbo, E.B.; Johnny, I.I.; Anagboso, M.O.; Ebong, N.O. Genotoxic and cytotoxicity activities of *Setaria megaphylla.* Asian J. Biochem., Gene. Mol. Biol. 2023, 15, 56-64. https://doi.org/10.9734/ajbgmb/2023/v15i3308
31. Swierenga, S.H.H.; Heddle, J.A.; Sigal, E.A. 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. Mut. Res. 1991, 246, 301–322. https://doi.org/10.1016/0165-1110(91)90035-G
32. Olorunfemi, D.I.; Olomukoro, J.O.; Anani, O.A. Toxicity evaluation and cytogenetic screening of process water using a plant bioassay. Nig. J. Basic Appl. Sci. 2015, 23, 31-37. https://doi:10.4314/njbas.v23i1.5
33. G¨om¨urgen, A.N. Cytological effect of the potassium metabisulphite and potassium nitrate food preservative on root tips of *Allium cepa* L. *Cytologia*. 2005, 70, 119– 128. https://doi.org/10.1508/CYTOLOGIA.70.119
34. T¨urkoglu, S. Genotoxicity of five food preservatives tested on root tips of *Allium cepa* L. Mut. Res./Gen. Toxicol. Environ. Mutagen. 2007, 626, 4–14. https://doi.org/10.1016/j.mrgentox.2006.07.006
35. Sharma, A.; Sen, S. Chromosome Botany, Science, Enfield, NH, USA, 2002.
36. Fadoju, O.M.; Osinowo, O.A.; Ogunsuyi, O.I.; Oyeyemi, I.T.; Alabi, O.A.; Alimba, C.G.; Bakare, A.A. Interaction of titanium dioxide and zinc oxide nanoparticles induced cytogenotoxicity in *Allium cepa*. Nucleus. 2020, 68, 159-166. https://doi:10.1007/s13237-020-00308-1
37. Albertini, R.J.; Anderson, D.; Douglas, G.R. IPCS guidelines for the monitoring of genotoxic effects of carcinogens in humans. Mutation Res. 2000, 463, 111–172. https://doi.org/10.1016/S1383-5742(00)00049-9
38. Krishna, G. Hayashi, M. In vivo rodent micronucleus assay: protocol, conduct and data interpretation," Mutation Res. 2000, 455, 155–166. https://doi.org/10.1016/S0027-5107(00)00065-6
39. Soliman, M.I. Genotoxicity testing of neem plant (*Azadirachta indica* A. Juss.) using the *Allium cepa* chromosome aberration assay. J. Biol. Sci. 2001, 1, 1021–1027. https://doi:10.3923/jbs.2001.1021.1027
40. Akinboro, A.; Bakare, A.A. Cytotoxic and genotoxic effects of aqueous extracts of five medicinal plants, J. Ethnopharmacol. 2007. 112, 470–475. https://doi.org/10.1016/j.jep.2007.04.010
41. As, T.; kınelik, C.; Aslanturk, O.S. Cytotoxic and genotoxic effects of *Lavandula stoechas* aqueous extracts Biologia. 2007, 62, 292–296. https://doi.org/10.2478/s11756-007-0050-5
42. As, T.A.; kin, C.; Aslanturk, O.S. Investigation of cytotoxic and genotoxic effects of *Ecballium elaterium* juice based on *Allium* test," Meth. Find. Exp. Clin. Pharmacol. 2009, 31, 591–596. https://doi.org/10.1358/mf.2009.31.9.1405622

https://doi.org/10.56717/jbt.2025.v01i01.03

43. Okopide, E.; Johnny, I.I.; Olamide, F.; Okokon, J.E. GC-MS analysis, in vitro antioxidant, genotoxic and cytotoxic activities of fruit extract of *Solanum anomalum.* Sumerianz J. Biotech. 2024, 7, 76-88. https://doi.org/10.47752/sjb.74.76.88
44. Osigwe, C.C.; Okokon, J.E.; Wilfred, U.; Uwaeme, U.F.; Johnny, I.I. Evaluation of cytotoxic and genotoxic activities of *Croton zambesicus* Muell Arg. leaf extract in rats. Trends Nat. Prod. Res. 2025, 6, 1-9. https://doi.org/10.61594/tnpr.v6i1.2025.116
45. Osigwe, CC.; Okokon, J.E.; Uwaeme, U.F.; Jonny, I.I. Genotoxic and cytotoxic activities of leaf extract of *Stachytarpheta cayenensis* (Rich). Vahl. Asian J. Biochem., Genet. Mol. Biol. 2025, 17, 22-31. https://doi.org/10.9734/ajbgmb/2025/v17i445
46. Osigwe, C.C.; Okokon, J.E.; Uwaeme, U.F.; Mmekam, E.; Johnny, I.I. Evaluation of genotoxic and cytotoxic activities of corn silk (*Stigma maydis*) extract of *Zea mays* L. Asian J. Biochem. Genet. Mol. Biol. 2025, 17, 92- 100. https://doi:10.9734/ajbgmb/2025/v17i4461
47. Garg, A.; Malhotra, R.; Urs, A.B. Ghost cells unveiled: A comprehensive review. J. Oral Biosci. 2022, 64(2):202-209. https://doi.org/10.1016/j.job
48. Park, W.; Wei, S.; Kim, B.S.; Kim, B.; Bae SJ.; Chae, Y.C.; Rvu, D.; Ha, K.T. Diversity and complexity of cell death: A historical review. Exper. Mol. Med. 2023, 55, 1573–1594. https://doi.org/10.1038/s12276-023-01078-2
49. Agus, H.H. Oxidative stress and dietary antioxidants. In Toxicology Patel VB and Preedy VR. Eds. 2021, 33-42. https://doi.org/10.1016/c2018-0-04534-x

https://doi.org/10.56717/jbt.2025.v01i01.03