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NEUROPROTECTIVE POTENTIAL OF *MORINGA OLEIFERA* AND *UVARIA NARUM* LEAF EXTRACTS ON GLYPHOSATE-INDUCED DOPAMINE NEURON DEGENERATION IN *CAENORHABDITIS ELEGANS*

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ABSTRACT

India harbours an indigenous hub of medicinal plants and herbs that have been used colloquially for the treatment and management of various occupationally induced neurological disorders such as Parkinson's disease (PD). In the present study, we studied the neuro protective potential of *Moringa oleifera* and *Uvaria narum* leaf extracts in glyphosate induced dopaminergic toxicity in *C. elegans*. Experimentations included assessment of dopamine neuron degeneration in terms of visualization of breaks, blebs and kinks in the anterior dendrites of the worms, changes in the pharyngeal pumping ability, worm motility screening and percentage of neuro protection offered by the leaf extracts.

M. oleifera and *U. narum* successful decreased the neuro toxic effect of glyphosate on the dopamine neurons by 3.3and 2.2 folds as compared to GLY. Neuro protective potential of *M. oleifera* and *U. narum* leaf extracts was found to be 60% and 30%. Furthermore *M. oleifera* reported 1.6 fold and *U. narum* 1.4 fold increase in the rate of pharyngeal pumping as compared to the GLY arm and significantly improved the movement activity of the worms as assessed by optical inter ferometry.

M. oleifera and *U. narum* offer significant neuroprotection against GLY-induced dopamine neuron degeneration in *C. elegans* and hold a promising future for further investigation at clinical interface as a potential therapeutic agent for the management of PD.

***Keywords*:** Glyphosate, *C. elegans,* dopamine, plant extracts, Arena Tracker, Pharyngeal

Introduction

Glyphosate (GLY 41% SL), is an effective weedicide that is used in agriculture (Junaid & Gokce, 2024) and inhibits the enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSP) found in plants and microorganisms (Ferrante *et al*., 2023; Muñoz *et al*., 2023). Its contamination has also been reported in non-occupational routes of exposure as urine and blood, (Cellier *et al*., 2022; Filippi *et al*., 2024; Muñoz *et al*., 2023) and certain food sources such as cereals (Pérez-Lucas *et al*., 2024).

With an aging population, neuro degeneration is a serious worry since it can result in conditions like dementia and difficulties in mobility. India harbours an indigenous hub of medicinal plants and herbs that have been used colloquially for the treatment of various occupationally induced neurological disorders such as Parkinson's disease (PD), with a constant interest in the use of plants as therapeutic agents for slowing/ ameliorating their progression. Recently (Jadhav *et al*., 2025) have also reported the efficacy of *Withania somnifera* (Ashwagandha) plant extract in mitigating neuronal damage caused by glyphosate-induced neuronal toxicity in *C. elegans* (doi.org/10.51470/Plant Archives.2025.v25.no.1.218). It is further reported that the phytochemicals /bioactive that are present in the plant extracts may exhibit many healing properties that make them ideal as therapeutic agents. Amongst the

many plants that are used in the conventional treatment of numerous diseases, *Moringa oleifera* (*M. oleifera*) and *Uvaria narum* (*U. narum*) are largely investigated for their broad-spectrum ameliorative potentials in numerous diseases. Both are native to India and widely cultivated in the tropical- subtropical belt of Asia and Africa (Worku & Tolossa, 2024). Many of the health benefits of *M. oleifera* are attributed to the abundant quantity of phenolics, thiocyanates and flavonoids it contains. Various parts of the plant such as the leaves, roots and seeds are utilized for therapy of neurological disorders (Saleh *et al*., 2025). Similarly *U. narum* is particularly present in the southern belt of the Indian peninsula, particularly in the forests of Western Ghats. It shows therapeutic benefits and an extensive phytochemical profile of phenols, tannins, and antioxidants. The bioactive in *U. narum* have been linked to their anticancer, anthelmintic, hepatoprotective, and antibacterial properties and find much applications in the treatment of rheumatic infections, eczema, jaundice, and gastrointestinal issues (Christopher, 2022).

Many *in vitro*/*in vivo* models have been employed in laboratories to study Parkinson's disease mechanism of action (Ali *et al*., 2019; Ali & Rajini, 2016). However, *C. elegans* offers many advantages to study pesticide-induced neurotoxicity because of its transparent body and availability of many transgenic and mutant strains. The shared conservation in its molecular and cellular pathways offers rapid analyses for pathological mechanisms (Jafri Ali & Sharda Rajini, 2013).

Likewise in the present study, we studied the neuroprotective potential of M. oleifera and *U. narum* leaf extracts in GLY induced dopamine toxicity in *C. elegans.* Analysis of neurotoxicity was done for the following parameters such as dopamine neuron degeneration assessed in terms of visualization of breaks, blebs and kinks in the anterior dendrites, alteration in pharyngeal pumping, motility screening and percentage neuroprotection by *M. oleifera* and *U. narum* leaf extracts. Since traditional management of PD only provides symptomatic relief, new research in today's times is focused on discovering new plants exhibiting therapeutic potential for PD. Considering that synthetic drugs are known to cause many undesired effects, medicinal plants, natural bioactive molecules and herbal formulations are gaining much momentum in recent times.

Materials & Methods

Plant Materials

Moringa oleifera (Drumstick)and, *Uvaria narum* (Kariballi) leaves were bought from the local Market and further verified at the Department of Agriculture, University of Agriculture, Raichur, Karnataka, India.

Plant extracts

The leaves of the above-mentioned plants were washed using distilled water and further dried in shade. They were subsequently powdered and dissolved in distilled water (1g sample was dissolved in 10ml of water) in an electric blender for 10 min and further filtered through a Whatman filter paper-1 and stored at 4ºC in falcon tubes till further analysis. 600µg/ml of plant extract was used for experiments based on initial mortality studies.

C. elegans strains

N2 and transgenic strain BZ555 (dat-1p:: GFP tagged) were purchased from *Caenorhabditis* Genetics Centre (CGC, University of Minnesota, USA), (Nass & Blakely, 2003). Briefly, worms were grown on nematode growth media (NGM) with *Escherichia coli* (OP_{50} strain -auxotrophic for uracil) for food and maintained at 20ºC. Bleaching was performed to get worm eggs (12% NaOCl and 10% 1 M NaOH) that were washed with M9 buffer and seeding on NGM plates with no food source. They were subsequently incubated overnight at 20ºC to obtain newly hatched larvae of the L1 stage. The stock solution of GLY41% SL was prepared in sterile distilled water at final concentration of 10mM ($1/7^{th}$ LC_{50} (71.54 mM) (Zhihang *et al*., 2024). All experiments were repeated thrice at three different days using between 50-100 worms.

Dopamine neuron degeneration and protection assay

The neuron degeneration and neuroprotection assay were performed following protocols from (Anjaneyulu *et al*., 2020; Bijwadia *et al*., 2021), with slight modifications. Briefly, synchronized L-1 BZ555 larvae were exposed to (600µg/ml) *M. oleifera* and *U. narumin* a 24-well plate. Post 24hrs of exposure, they were rinsed with M9 buffer and further dopamine neurons imaging was performed. Immobilized of worms for imaging was done using 20 mM of sodiumazide in 96 well imaging plates (Ali and Rajini, 2012). Neurodegeneration and neuroprotection of neurons by plant extracts were analysed by scoring of the breaks, kink and blebs of the worm's dendrites using LUMASCOPE 720 fluorescence microscope with excitation wavelengths ranging from 784 to 490 nm at 80X magnification. Neurodegeneration (seven-point scale assessment) was considered if one of the four CEP dendrites exhibited partial or complete loss of green fluorescence signal either as breaks, blebs or kinks. The number of worms exhibiting degeneration

was counted in each group and the results were expressed as the percentage neurodegeneration. The experiment was done in triplicates and 50 images were analysed in each group.

Calculations for neurodegeneration by GLY and neuroprotection by plant extracts was performed following protocol from (Anjaneyulu *et al*., 2020)

Percentage of worms with neuron degeneration was based on the protocol from (Jadav *et al*., 2025) namely

Neuron degeneration = (number of worms with degenerated neurons/total number of worms) *100

Neuroprotection was calculated using protocol also from (Jadav *et al*., 2025)

Neuroprotection (%) = percentage of worms with neurodegeneration in the GLY-treated group - percentage of worms with neurodegeneration in the extract-treated group.

100 worms were analysed in each group. The experiments were repeated three times on three different days.

Mobility assay as quantified by the Arena Tracker

The mobility assay was done based on (Bauer *et al*., 2022; Kutzner *et al*., 2024) that detects positional changes in the worms movement using repeated scanning. Briefly worms were exposed to (600µg/ml) plant extracts from *M. oleifera* and *U. narumin* a 24-well plate for 6hrs. Worm position and movement were tracked using WMicroTracker ARENA System LED micro-beams on the culture dishes and interruptions of the LED micro-beam by a worm's movement allowed real-time data to be processed at time points 0, 0.5, 4 and 12 hrs. Inbuilt software detected the changes in the worm positions during scans and derived an activity score based on the successive scan differences. 70 worms were analysed in each group of experimentation which was repeated thrice at three different days.

Health span assay for pharyngeal pumping

The assay for pharyngeal pumping was conducted using previously published literature (J J. O'Brien, 2022). Briefly L4 worms were rinsed with M9 buffer and further exposed to (600µg/ml) plant extracts from *M. oleifera* and *U. narum* for 10 min. Pharyngeal pumping was done by counting the number of grinder movements made by the worms in 30 sec of observation under a stereo-binocular microscope. An average of 50 worms were analysed in each group. The experiment was repeated thrice at three different days.

Statistics

GraphPad Prism version 9.0.0 was used for statistical analysis based on the Mean ± S.E values (n=50, 70 and 100). Analysis of data analysis was through 1& 2 way ANOVA and (Tukey Multiple Comparison Test) post-hoc analysis ($p<0.0001$).

Results

Neuroprotective effect of *M. oleifera* and *U. narum* leaf extracts on GLY-induced dopamine neuron degeneration

The neuroprotective potential of *M. oleifera* and *U. Narum* leaf extracts, on GLY induced neurodegeneration was studied in *C. elegans* by assessing the amount of total neurodegenerations produced in the individual groups and as seen in the amount of break, blebs and kinks that were produced in the four CEP dendrites and associated loss in signal intensity of the GFP tag that was attached to the neurons. On analysis of neurodegeneration that was produced in the all arms of the study, highest neurodegeneration was observed in the GLY arm –4.4 folds higher as compared to the control group, followed by GLY + U. narum with 2.2 folds increased neurodegeneration and GLY + *M. oleifera* with 1.1-fold as compared to the control group. *M. Oleifera* decreased the toxicity of the GLY arm by 3.3 folds as compared to *U. narum* that was able to nullify the GLY arm toxicity by 2.2 folds in the combination studies. Similarly, as compared to the two plant extracts maximum neuroprotective effect was seen with the *M. oleifera* leaf extract as compared to that from the leaf extract from *U. narum.*

On analysis of neurodegeneration that was analysed in the form of breaks, highest neurodegeneration was observed in the GLY arm – 15.3 folds higher as compared to the control group, followed by GLY + *U. narum* with 6.3 folds and GLY + *M. oleifera* with 3.3 fold increase in toxicity of the CEP dendrites. *M. oleifera* decreased the toxicity of the GLY arm by 1.9 folds as compared to *U. narum* in the combination studies. Similarly, as compared to the two plant extracts maximum neuroprotective effect was seen with the *M. oleifera* leaf extract as compared to *U. narum.*

Degeneration in terms of the blebs formation was seen highest for GLY arm - 14 folds higher as compared to control, followed by GLY + *U. narum* then GLY + *M. oleifera*. Comparing GLY vs GLY + plant extract groups, the GLY + *M. Oleifera* reported 87% decrease in toxicity, and GLY + *U. narum* reported 47% decrease in toxicity. Comparing the plant

extract groups, maximum neuroprotective effect was seen again in *M. oleifera* followed by *U. narum* group.

Furthermore, on analysis of the kink's formation from GLY toxicity, data obtained showed insignificance statistics on comparing control vs GLY, control vs GLY + *M. oleifera* and GLY + *U. narum* groups. Data was analysed by 2-way ANOVA followed by post-hoc analysis (Tukey Multiple Comparison Test). Conclusively, as compared to the GLYarm, GLY + *M. oleifera* caused 25% and GLY + *U. narum* -50% neurodegeneration in the neurons.

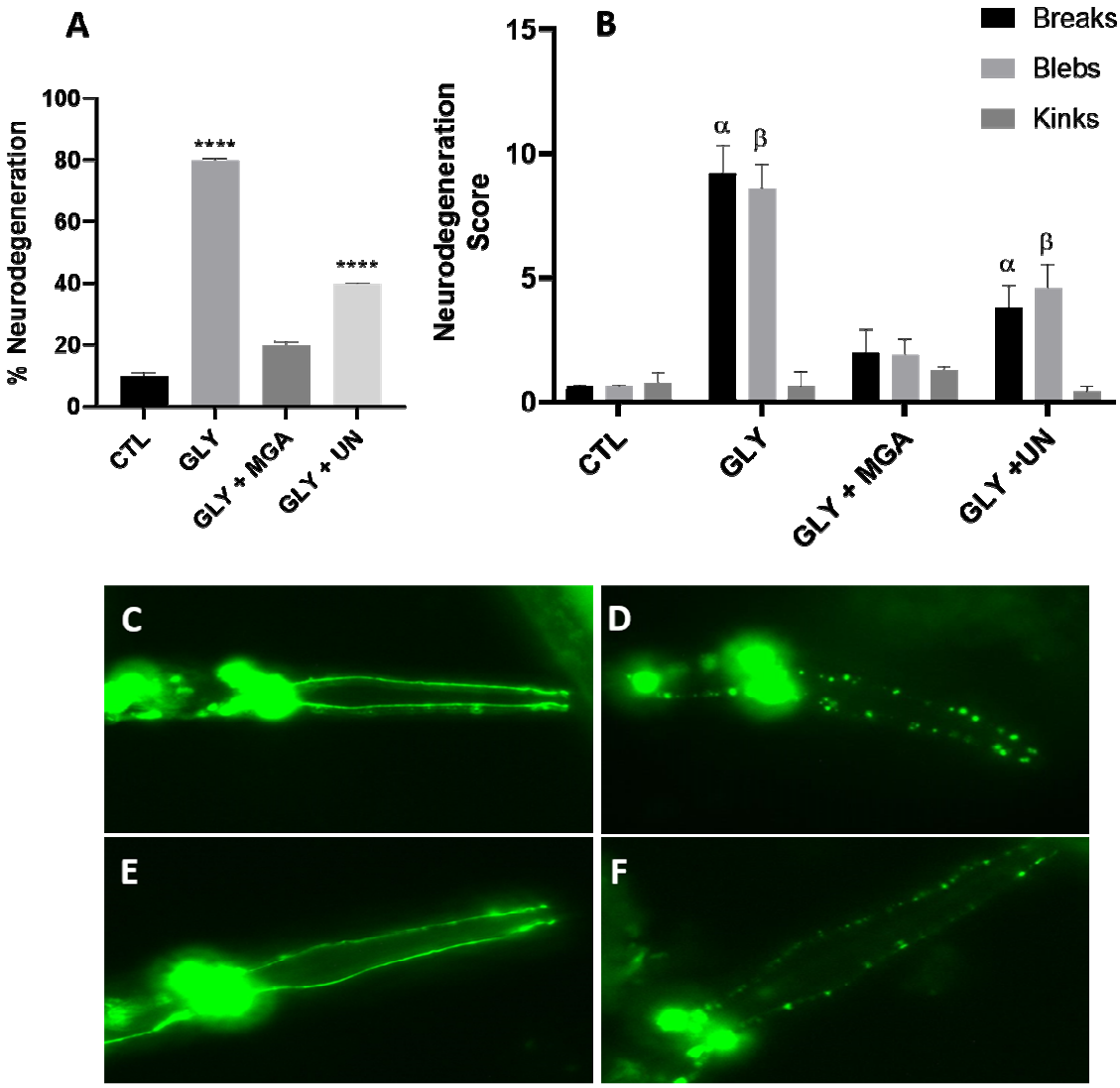

Fig. 1 : Glyphosate -induced toxicity and the neurodegeneration observed in *M. oleifera* and *U. narum* leaf extracts in *C. elegans*

A: Percentage neurodegeneration in different treatment groups **B:** Breaks (α): groups significantly different from control. Blebs (β): groups significantly different from control **C:** Control **D:** Glyphosate treated **E:** M. *Oleifera treated* **F:** U. narum treated

Values represented are Mean ± S.E (n=50). Data analysed by 2 way ANOVA followed by post-hoc analysis (Tukey Multiple Comparison Test). **:** **** significant degeneration as compared to control; ($p<0.0001$).

Neuroprotective effect of *M. oleifera* and *U. narum* leaf extracts on *C. elegans*

The plant extracts of *M. oleifera* and *U. narum* used at a concentration of 600µg/ml/ along with GLY, showed variable neuroprotection against GLY 41% SL-induced dopamine neurodegeneration in *C. elegans*. The highest neuroprotection was observed for *M. oleifera* (60%) followed by *U. narum* (30%). Data analysed by 1 way ANOVA followed by post-hoc analysis (Tukey Multiple Comparison Test). As compared to the GLY arm, neuroprotection offered by M. oleifera leaf extract was 6 folds higher at **** $p<0.0001$ significance. U. narum leaf extract showed 3 folds higher neuroprotection as compared to GLY arm with a statistical significance of ** at $p<0.001$.

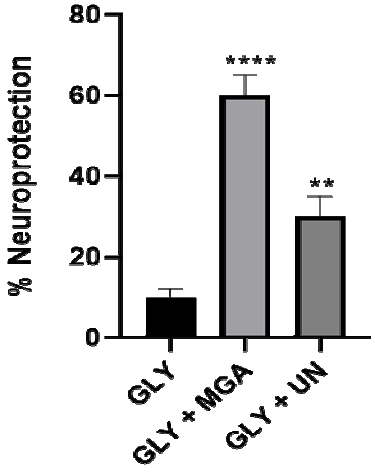

Fig. 2 : Neuroprotection by *M. oleifera* and *U. narum* leaf extracts on glyphosate induced toxicity in *C. elegans*

Values represented are Mean ± S.E (n=100). Data analysed by 1 way ANOVA followed by post-hoc analysis (Tukey Multiple Comparison Test). **:** **** significant as compared to glyphosate ($p<0.0001$).** significant as compared to glyphosate ($p<0.001$).

Effect of *M. oleifera* and *U. narum* leaf extracts on the rate of pharynx pumping in *C. elegans*

In the present study we found that as compared to control, GLY arm registered apharyngeal pumping rate of 57.89%that is (42.11% lower than control). Similarly GLY + *M. oleifera* reported a pharyngeal pumping rate of 92.1% around (7.9 % lesser than control) and GLY + U. narum showed pumping efficacy of 81.5% (18.5 lesser as compared to control). Comparing with GLY, GLY + M. oleifera reported 1.6 fold increase and GLY + U. narum1.4 fold increase in rate of pharyngeal pumping. Similarly maximum effect of the plant extract on feeding efficiency was observed in the following order: *M. oleifera*>*U. narum*

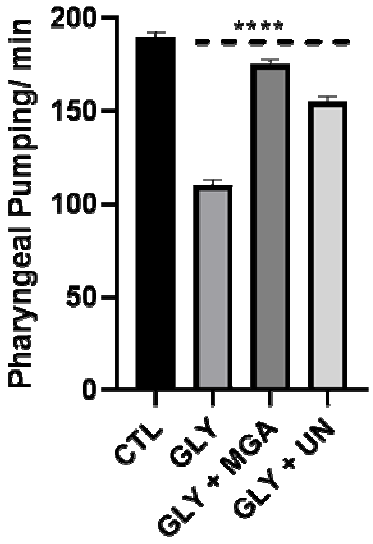

Fig. 3. : *M. oleifera* and *U. narum* leaf extracts ameliorate the rate of pharynx pumping in *C. elegans* against glyphosate induced toxicity

Values represented are Mean ± S.E (n=100). Data analysed by 1 way ANOVA followed by post-hoc analysis (Tukey Multiple Comparison Test). **:** **** significantly increased as compared to glyphosate ($p<0.0001$).

Effect of leaf extracts on the movement activity in GLY- induced toxicity in *C. elegans* (BZ-555) using Arena tracker

The mobility assay utilized scans generated from infrared LED micro-beams from the WMicroTracker ARENA System that tracked the movement and positions of the worms as activity units on the culture dishes and allowed real-time data to be processed at different time points as 0, 0.5, 4 and 12 hrs. Results of the motility activity established that except the *M. oleifera* arm all other treatment groups showed a time dependent decrease in the static and dynamic movement activities of the worms. From 0.5-12 hr plant extract from *M. oleifera* arm showed a statistically significant increase in their motility that ranged from (0 hr-36.91 units IR activity vs 0.5 hr-39.24 units IR activity vs 12 hrs-38.91 units IR activity). Since at 12 hr exposure, worms failed to show any significant motility activity as compared to control arm, further exposure was terminated.

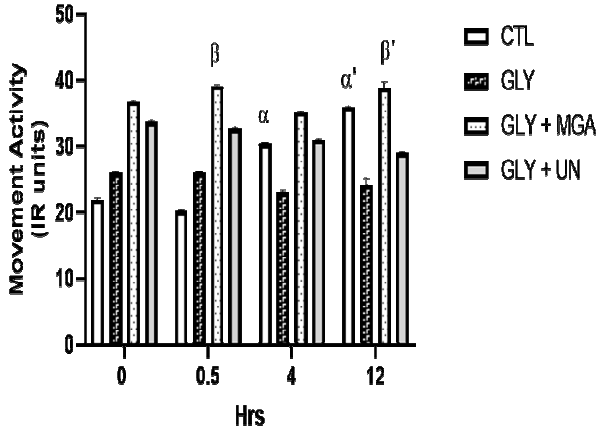

Fig. 4 : Effect of *M. oleifera* and *U. narum* leaf extracts on the movement activity in different treatment groups of glyphosate induced toxicity in *C. elegans* (BZ-555) at different time points using Arena tracker

Behaviour of worm population at different treatment groups at 0 hrs, 0.5 hrs, 4 hrs and12 hrs

Values represented are Mean ± S.E (n=75). Data analysed by 2-way ANOVA followed by post-hoc analysis (Tukey Multiple Comparison Test).

An increase in movement activity was observed in the control groups b/w 0 hrs vs 4hr (α**:** **** significant, p<0.0001) and 0 hrs vs12 hrs (α'**:** *** significant, p<0.001) using optical interfero metry. Similarly, movement activity was increased in the *M. oleifera* groups b/w 0 hrs vs 0.5 hr (β**:** *** significant, p<0.0002) and 0 hrs vs12 hrs (β'**:** ** significant, p<0.001)

Discussion

Occupationally induced pesticide toxicity and neurodegeneration has been previously reported (Ali, 2020). Synthetic drugs are the usual preferred choice for treatment in many cases of PD, however, they do come with their set of side effects (Kaspute *et al*., 2025). This has led to a burgeoning interest in exploring plant based therapy as an alternative approach for the management of PD and exploring plant bioactives that could be used in the management and possible mitigation of such debilitating diseases (Nahar *et al*., 2025). Likewise, the main objective of our study was to screen *M. oleifera* and *U. narum* plants that are native to the Indian peninsula, for their potential to mitigate GLY induced dopamine neuron toxicity in *C. elegans*. The choice of the plants was based on their popularity as broad-spectrum curative agents to many ailments locally.

C. elegans was chosen as a model organism to mimic PD, as it has distinctly 302 neurons all of which are fully mapped (Bargmann, 1998). There are 8 dopaminergic neurons (DA), 6 in the anterior (4 CEP neurons and 2 ADE neurons) and 2 in the posterior as PDE neurons (Sulston *et al*., 1975). Furthermore, it has a transparent body that makes visualization of the fluorescent neurons in many mutant and transgenic strains easy and comprehensive.

On analysis of neurodegeneration induced by GLY, our studies highlighted that *M. oleifera* leaf extract was able to successfully decrease its toxicity by 3.3 folds and *U. narum* by 2.2 folds. As compared to *U. narum, M. oleifera* leaf extract was more ameliorative in reverting the GFP signal intensity in the anterior dendrites of the worms. The results of our study further reiterated a statistically relevant neuroprotective potential of *M. oleifera* (60%) and *U. narum* (30%) when compared to the GLY arm in the combination study. Many authors have investigated the potential of various medicinal /herbal plants for their neuroprotective effect in the past. (Arslan & Yılmaz, 2023) also studied the neuroameliorative potential of *Geranium robertianum* L. aqueous extract on the cellular PD modelling. Likewise in 2022, (Nghi *et al*., 2022) studied the antioxidant potential of Rumdul (*Sphaerocoryne affinis*) for PD outcomes. M. oleifera in particular has been studied previously for its neuroprotective potential and of late one research group investigated its effect on cobalt chloride-produced oxidative damage in the wistar rat Cerebellum (Olaniyan *et al*., 2025). Likewise Chukwu *et al*., 2025 in their preclinical study confirmed that *M. oleifera* Lam. mitigated the neurodevelopmental defects of prenatal stress in Wistar rats (Chukwu *et al*., 2025). Furthermore Carrotta *et al*., 2025, said that M. oleifera extracts cause a strong inhibition on the amyloid process involved in Alzheimer's disease (Carrotta *et al*., 2025). Likewise different species of the Uvaria have been investigated for their medicinal values. It is reported that researchers synthesised silver nano particles from the leaf extract of the medicinal plant *U. narum*, that exhibited antiangiogenic activity, cytotoxicity, and catalytic properties, crucial in its clinical applications (Ajaykumar *et al*., 2023). Similarly (Ly *et al*., 2022) studied the therapeutic potential of *Polyscias fruticosa* (L.) Harms leaf extract for PD treatment on drosophila melanogaster model.

The pharyngeal pumping of *C. elegans*, in normal healthy worms is between 250–300 pumps/min normally, which is a measure of the health span of the worm. Our results of pharynx pumping studies reiterated the neuroprotective efficacy of *M. oleifera* and *U. narum* plant extracts. *M. oleifera* reported 1.6 fold increase and *U. narum* 1.4 fold increase in rate of pharyngeal pumping when compared to the combination studies with GLY arm. Similar to our results a recently study of medicinal plants by Jadhav *et al*., also reported about the neuroprotective efficacy

of Ashwagandha, Brahmi and lemon in increasing the rate of pharyngeal pumping in *C. elegans* on exposure to neurotoxicants (Jadhav *et al*., 2025).Similar to our study, (Liu *et al*., 2023) and (Wei *et al*., 2025) also studied that pesticide fluopimomide and ferroptosis induced an oxidative stress and mitochondrial damage with reduced pharyngeal pumping as compared to control in their studies in *C. elegans*.

Automated worm monitoring using Worm Microtracker ARENA machine is a useful and quicker method for studying health span in *C. elegans* (Zavagno *et al*., 2023). It analyses the locomotory activity through infrared scattering by worm movements crossing the path of light in IR activity units/time. Results of the motility activity established that *M. oleifera* showed a time dependent increase in the static and dynamic movement activities of the worms. From 0.5-12 hr plant extract from *M. oleifera* arm showed a statistically significant increase in their motility that ranged from (0 hr-36.91 units IR activity vs 0.5 hr-39.24 units IR activity vs 12 hrs-38.91 units IR activity) which is a clear indication of the general wellbeing and good health of the worms till 12 hrs post GLY exposure. Our studies highlight the neuroprotective potential of *M. oleifera*. Similar to our study, a recent report by (Jadhav *et al*., 2025) also highlighted the potential of Ashwagandha in their motility study till 4 hr. (Thakkar *et al*., 2024) also reported Ashwagandha root extract conferring beneficial effects on health and lifespan of the worms. Taken together *M. oleifera* leaf extract showed high neuroprotective potential in terms of amelioration of dopaminergic damage, pharyngeal pumping and motility activity.

Conclusion

Our studies substantiate that GLY inflictsdopamine neuro degerneration at 10mM concentration. *C. elegans*. *M. oleiferaand U. narum* leaf extracts tested for amelioration showed varying degree of neuroprotection of dopaminergic system. We conclude that *M. oleifera* and *U. narum* leaf extracts offer substantial neuroprotection against GLY-induced toxicity and can be further investigated for their mechanism of protection in the worms.

Author Contributions

Kisan B Jadav: conceived, supervised, acquired grants and designed the experiments; data analysis and drafting the final manuscript; K. Shruthi Nagaral Sachin S Patil and: design of experiments, procurement of plant samples and first draft of manuscript; Ayyangouda Patil, experimental design, data interpretation and discussion.

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Conflict of Interest

The authors have no conflict of interest to report.

References

Ajaykumar, A. P., Mathew, A., Chandni, A. P., Varma, S. R., Jayaraj, K. N., Sabira, O., Rasheed, V. A., Binitha, V. S., Swaminathan, T. R., Basheer, V. S., Giri, S., & Chatterjee, S. (2023). Green Synthesis of Silver Nanoparticles Using the Leaf Extract of the Medicinal Plant, Uvaria narum and Its Antibacterial, Antiangiogenic, Anticancer and Catalytic Properties. *Antibiotics*, *12*(3), 564. https://doi.org/10.3390/antibiotics12030564

Ali, S.J. (2020). Monocrotophos, an organophosphorus insecticide, induces cortical and trabecular bone loss in Swiss albino mice. *Chemico-Biological Interactions*, *329*, 109112. https://doi.org/10.1016/j.cbi.2020.109112

Ali, S. J., Ellur, G., Patel, K., & Sharan, K. (2019). Chlorpyrifos Exposure Induces Parkinsonian Symptoms and Associated Bone Loss in Adult Swiss Albino Mice. *Neurotoxicity Research*, *36*(4), 700–711. https://doi.org/10.1007/s12640-019-00092-0

Ali, S. J., & Rajini, P. S. (2016). Effect of monocrotophos, an organophosphorus insecticide, on the striatal dopaminergic system in a mouse model of Parkinson's disease. *Toxicology and Industrial Health*, *32*(7), 1153–1165. https://doi.org/10.1177/0748233714547733

Anjaneyulu, J., R, V., & Godbole, A. (2020). Differential effect of Ayurvedic nootropics on C. elegans models of Parkinson's disease. *Journal of Ayurveda and Integrative Medicine*, *11*(4), 440–447. https://doi.org/10.1016/j.jaim.2020.07.006

Arslan, M. E., & Yılmaz, A. (2023). Neuroprotective effects of Geranium Robertianum L. Aqueous extract on the cellular Parkinson's disease model. *European Review for Medical and Pharmacological Sciences*, *27*(2), 570–579. https://doi.org/10.26355/eurrev_202301_31058

Bargmann, C. I. (1998). Neurobiology of the *Caenorhabditis elegans* Genome. *Science*, *282*(5396), 2028–2033. https://doi.org/10.1126/science.282.5396.2028

Bauer, K. C., York, E. M., Cirstea, M. S., Radisavljevic, N., Petersen, C., Huus, K. E., Brown, E. M., Bozorgmehr, T., Berdún, R., Bernier, L., Lee, A. H. Y., Woodward, S. E., Krekhno, Z., Han, J., Hancock, R. E. W., Ayala, V., MacVicar, B. A., & Finlay, B. B. (2022). Gut microbes shape microglia and cognitive function during malnutrition. *Glia*, *70*(5), 820–841. https://doi.org/10.1002/glia.24139

Bijwadia, S. R., Morton, K., & Meyer, J. N. (2021). Quantifying Levels of Dopaminergic Neuron Morphological Alteration and Degeneration in Caenorhabditis elegans. *Journal of Visualized Experiments*, *177*, 62894. https://doi.org/10.3791/62894

Carrotta, R., Vilasi, S., Costa, M. A., Librizzi, F., Martorana, V., Passantino, R., Buzzanca, C., Di Stefano, V., Ortore, M. G., Piccirillo, S., Preziuso, A., Magi, S., & Mangione, M. R. (2025). *MORINGA OLEIFERA* Extracts as Strategic Phyto‐Therapy for Alzheimer's Disease. *Food Science & Nutrition*, *13*(4), e70007. https://doi.org/10.1002/fsn3.70007

Cellier, M., Anthony, N., Bruneau, C., & Descatha, A. (2022). Determination of Glyphosate and AMPA in Blood Can Predict the Severity of Acute Glyphosate Herbicide Poisoning. *Laboratory Medicine*, *53*(4), 394–398. https://doi.org/10.1093/labmed/lmac002

Chaufan, G., Coalova, I., & Molina, M. D. C. R. D. (2014). Glyphosate Commercial Formulation Causes Cytotoxicity, Oxidative Effects, and Apoptosis on Human Cells: Differences With its Active Ingredient. *International Journal of Toxicology*, *33*(1), 29–38. https://doi.org/10.1177/1091581813517906

Christopher, R. (2022). Plant species of the genus *Uvaria*: Ethnobotanical uses, biological activities and phytochemistry. *Natural Product Research*, *36*(11), 2946–2961. https://doi.org/10.1080/14786419.2021.1929972

Chukwu, O. O., Iyare, C. O., Okorocha, A. E., Konyefom, N. G., Emelike, C. U., Onyeji, G. N., Igwe, N. P., & Ezimah, A. C. U. (2025). Moringa oleifera Lam. Is a potential mitigator of neurodevelopmental defects caused by prenatal stress in Wistar rats. *Jmpir*, *24*(93), 79 EP – 101.

Ferrante, M., Rapisarda, P., Grasso, A., Favara, C., & Oliveri Conti, G. (2023). Glyphosate and environmental toxicity with "One Health" approach, a review. *Environmental Research*, *235*, 116678. https://doi.org/10.1016/j.envres.2023.116678

Filippi, I., Fernández, P., Grimalt, J. O., Butinof, M., Amé, M. V., & Muñoz, S. E. (2024). Glyphosate and AMPA in saliva and other traditional human matrices. New findings for less invasive biomonitoring to the exposure to pesticides. *Environmental Advances*, *15*, 100474. https://doi.org/10.1016/j.envadv.2023.100474

J J. O'Brien, T. (2022). *Pharyngeal Pumping Assay v1*. https://doi.org/10.17504/protocols.io.b3hiqj4e

Jafri Ali, S., & Sharda Rajini, P. (2013). Elicitation of Dopaminergic Features of Parkinson's Disease in C. elegans by Monocrotophos, an Organophosphorous Insecticide. *CNS & Neurological Disorders - Drug Targets*, *11*(8), 993–1000. https://doi.org/10.2174/18715277311211080008

Junaid, M., & Gokce, A. (2024). GLOBAL AGRICULTURAL LOSSES AND THEIR CAUSES. *Bulletin of Biological and Allied Sciences Research*, *2024*(1), 66. https://doi.org/10.54112/bbasr.v2024i1.66

Kaspute, G., Ramanavicius, A., & Prentice, U. (2025). Natural drug delivery systems for the treatment of neurodegenerative diseases. *Molecular Biology Reports*, *52*(1), 217. https://doi.org/10.1007/s11033-025-10286-9

Kutzner, C. E., Bauer, K. C., Lackmann, J.-W., Acton, R. J., Sarkar, A., Pokrzywa, W., & Hoppe, T. (2024). Optogenetic induction of mechanical muscle stress identifies myosin regulatory ubiquitin ligase NHL-1 in C. elegans. *Nature Communications*, *15*(1), 6879. https://doi.org/10.1038/s41467-024-51069-3

Leino, L., Tall, T., Helander, M., Saloniemi, I., Saikkonen, K., Ruuskanen, S., & Puigbò, P. (2021). Classification of the glyphosate target enzyme (5-enolpyruvylshikimate-3-phosphate synthase) for assessing sensitivity of organisms to the herbicide. *Journal of Hazardous Materials*, *408*, 124556. https://doi.org/10.1016/j.jhazmat.2020.124556

Liu, H., Fu, G., Li, W., Liu, B., Ji, X., Zhang, S., & Qiao, K. (2023). Oxidative stress and mitochondrial damage induced by a novel pesticide fluopimomide in Caenorhabditis elegans. *Environmental Science and Pollution Research*, *30*(40), 91794–91802. https://doi.org/10.1007/s11356-023-28893-z

Ly, H. T., Nguyen, T. T. H., Le, V. M., Lam, B. T., Mai, T. T. T., & Dang, T. P. T. (2022). Therapeutic Potential of Polyscias fruticosa (L.) Harms Leaf Extract for Parkinson's Disease Treatment by Drosophila melanogaster Model. *Oxidative Medicine and Cellular Longevity*, *2022*, 1–18. https://doi.org/10.1155/2022/5262677

Muñoz, J. P., Silva-Pavez, E., Carrillo-Beltrán, D., & Calaf, G. M. (2023). Occurrence and exposure assessment of glyphosate in the environment and its impact on human beings. *Environmental Research*, *231*, 116201. https://doi.org/10.1016/j.envres.2023.116201

Nahar, L., Charoensup, R., Kalieva, K., Habibi, E., Guo, M., Wang, D., Kvasnica, M., Onder, A., & Sarker, S. D. (2025). Natural products in neurodegenerative diseases: Recent advances and future outlook. *Frontiers in Pharmacology*, *16*, 1529194. https://doi.org/10.3389/fphar.2025.1529194

Nass, R., & Blakely, R. D. (2003). The *Caenorhabditis elegans* Dopaminergic System: Opportunities for Insights into Dopamine Transport and Neurodegeneration. *Annual Review of Pharmacology and Toxicology*, *43*(1), 521–544. https://doi.org/10.1146/annurev.pharmtox.43.100901.135934

Nghi, N. B. T., Uyen, T. T., Anh, H. M., Linh, D. M., & Thao, D. T. P. (2022). Rumdul (Sphaerocoryne affinis) Antioxidant Activity and Its Potential for Parkinson's Disease Treatment. *Oxidative Medicine and Cellular Longevity*, *2022*, 1–12. https://doi.org/10.1155/2022/8918966

Olaniyan, I. O., Ajibade, A. J., Offiong, I. E., & Adebayo, T. O. (2025). Neuroprotective Effects of Moringa Oleifera Extract Against Cobalt Chloride-Induced Oxidative Damage in the Cerebellum of Male Wistar Rats. *Asian Journal of Research in Medical and Pharmaceutical Sciences*, *14*(1), 45–58. https://doi.org/10.9734/ajrimps/2025/v14i1295

Peillex, C., & Pelletier, M. (2020). The impact and toxicity of glyphosate and glyphosate-based herbicides on health and immunity. *Journal of Immunotoxicology*, *17*(1), 163–174. https://doi.org/10.1080/1547691X.2020.1804492

Pérez-Lucas, G., Navarro, G., & Navarro, S. (2024). Understanding How Chemical Pollutants Arise and Evolve in the Brewing Supply Chain: A Scoping Review. *Foods*, *13*(11), 1709. https://doi.org/10.3390/foods13111709

Saleh, A. Y., Saputra, D. A. Y., Valentina, R., & Susanto, T. D. (2025). The Miracle Moringa Oleifera Tree: A

Bibliometric Review of Its Neuroprotective Properties. *Pharmacognosy Journal*, *17*(2), 258–276. https://doi.org/10.5530/pj.2025.17.33

Sulston, J., Dew, M., & Brenner, S. (1975). Dopaminergic neurons in the nematode *Caenorhabditis elegans*. *Journal of Comparative Neurology*, *163*(2), 215–226. https://doi.org/10.1002/cne.901630207

Thakkar, N., Gajera, G., Mehta, D., Nair, S., & Kothari, V. (2024). *Withania somnifera root extract (LongeFera-TM) confers beneficial effects on health and lifespan of the model worm Caenorhabditis elegans*. https://doi.org/10.1101/2024.08.01.606126

Wei, J., Zhang, Y., Shi, W., Lu, L., Zhou, Q., Pu, Y., & Yin, L. (2025). Copper exposure induces neurotoxicity through ferroptosis in C. elegans. *Chemico-Biological Interactions*, *407*, 111369. https://doi.org/10.1016/j.cbi.2024.111369

Worku, B., & Tolossa, N. (2024). A Review on the Neuroprotective Effect of *Moringa oleifera*. *Oxidative Medicine and Cellular Longevity*, *2024*(1), 7694516. https://doi.org/10.1155/2024/7694516

Zavagno, G., Raimundo, A., Kirby, A., Saunter, C., & Weinkove, D. (2023). Rapid measurement of ageing by automated monitoring of movement of C. elegans populations. *GeroScience*, *46*(2), 2281–2293. https://doi.org/10.1007/s11357-023-00998-w

Zhihang, H., Ezemaduka, A. N., Hongxia, C., Yan, P., Yiwen, G., Nan, Z., Xinrui, L., Shan, G., Guojun, L., Jing, Y., & Bo, X. (2024). The joint toxicity effect of glyphosate and cadmium in a concentration-dependent manner on nematode Caenorhabditis elegans. *Ecotoxicology and Environmental Safety*, *285*, 117081. https://doi.org/10.1016/j.ecoenv.2024.117081