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Activated charcoal from green coconut as an alternativeto remove 2,4-D from water and reduce toxicity in Lactuca sativa L.

Carvão ativado de coco verde como alternativa para remover 2,4-D da água e reduzir toxicidade em Lactuca sativa L.

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mitotic index
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ABSTRACT
Water quality is essential for the maintenance of all forms of life on the planet since the consumption of contaminated water can pose health risks. In this study, green coconut-activated charcoal was used in the treatment of contaminated water at concentrations of 2, 5, 10, and 20 mg/L of the herbicide dichloro phenoxy acetic acid (2,4-D). Toverify the efficiency of the adsorption process, germination bioassays, and cytogenetic analyses were performed with seeds of Lactuca sativa L. as bioindicator. The germination bioassays were carried out with a germination paper roll in triplicate, with 300 seeds per treatment. As for the cytogenetic analysis, 3000 cells were analyzed per treatment. The results showed that the green coconut activated charcoal has adsorptive potential to remove 2,4-D from water, with germination results of 89.6% for treated water, 92% for pure water, and 0% for contaminated water. In the cytogenetic analysis, the Mitotic Index (MI) values were high and did not differ statistically for the pure and treated water sample, since the average between the four concentrations was 11.41 for the pure water sample, 10.64 for the treated and 7.15 for the contaminated water samples. As for chromosomal abnormalities (CA), there was a gradual increase from 0.47 to 1.10 according to exposure to 2,4-D concentrations. We thus conclude that 2,4-D has a toxic action for the development of lettuce seeds, and activated carbon from green coconut was efficient in adsorption.

Palavras-Chave
índice mitótico
poluição hídrica
ciclo celular
indicador biológico

RESUMO
A qualidade da água é indispensável para a manutenção de todas as formas de vida do planeta, umavez que oconsumo de água contaminada pode oferecer riscos à saúde. Neste trabalho foi utilizado o carvão ativado de coco verde no tratamento da água contaminada nas concentrações de 2, 5, 10 e 20 mg/L do herbicida ácidodiclorofenoxiacético (2,4-D). Para verificar a eficiência do processo de adsorção foram realizados bioensaios de germinação e análise citogenética com sementes de *Lactuca sativa L.* como bioindicador. Os bioensaios de germinaçãoforam feitos em rolo de papel de germinação em triplicata, totalizando 300 sementes por tratamento, e para a análise citogenética foram analisadas 3.000 células por tratamento. Os resultados obtidos mostraram que ocarvão ativado de coco verde possui potencial adsortivo para remover o 2,4-D da água, com resultados de germinação de 89,6% para água tratada, 92% para água pura e 0% para águacontaminada. Na análise citogenética os valores de Índice Mitótico (IM) foram altos e nãodiferiram estatisticamente para as amostras de água pura e tratada, uma vez que a média entre as quatro concentrações foi 11,41 para amostras de água pura, 10,64 para amostras tratadas e de 7,15 para as amostras de água contaminada. Quanto as anormalidades cromossômicas (AC) houve um aumento gradual de 0,47 para 1,10 conforme exposição às concentrações de 2,4-D. Concluímos assim que o 2,4-D possui ação tóxica para o desenvolvimento das sementes de alface, e o carvãoativado de coco verde se mostrou eficiente na adsorção.

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Introduction

Water is essential when it comes to the maintenance of all forms of life on Earth.Its use must be sustainable and rational because it is a resource of great social and economic value.When poorly managed, the characteristics of water can be compromised (WHO; DODDS, PERKIN, GERKEN, 2013; BEHMEL et al., 2016).

One of the major causes of water contaminationis the presence of herbicides, including 2,4-D (dichloro phenoxyaceticacid), which is an organic, systemic selective herbicide for the control of weeds, including broadleaf ones (AQUINO et al., 2007), and has been widely used since the 1940s (ISLAM et al., 2018). Since 2,4-D is anelective herbicide, it only affects dicots, not monocots (GROSSMANN, 2003). Therefore, it is used to combat weeds in soybean, corn, wheat, rice, and sugarcane crops, as well as pastures (ZAFRA-LEMOS et al., 2021). There are about 1,500 herbicides/pesticides that contain 2,4-D as their main ingredient (AYLWARD; HAYS, 2008), and which are widely used all around the world (CHEN et al., 2018). When applied to target plants, it acts as an auxin signaling agent, which leads to uncontrolled plant growth, epinasty, and death (GOGGIN; CAWTHRAY; POWLES, 2016; GROSSMANN, 2010).

The effect of 2,4-D on non-target organisms is alarming. In animals, studies report interference of 2,4-D with the metabolism of fish, amphibians, insects, rodents, and small ruminants (STEBBINS-BOAZ et al., 2004; LACHAPELLE et al., 2007; CATTANEO et al., 2008; FONSECA et al., 2008; MICHAUD; PARK; KWAK, 2010; VARGAS, 2010; IKECHUKWU et al., 2012; MENEZES et al., 2015; LAJMANOVICH et al., 2015; FREYDIER; LUNDGREN, 2016; DAKHAKHNI; RAOUF, QUSTI, 2016; AMEL et al., 2016; ZAFRA-LEMOS et al., 2021). When it comes to humans, some studies relate infertility in men to exposure to 2,4-D in cases in which spermatozoids, when exposed to this contaminant, had their total/progressive mobility anda bility to penetrate a viscous medium compromised. This indicates that exposure to 2,4-D and its accumulation in seminal plasma may increase infertility risks, as stated by TAN et al., 2016).

Therefore, itis necessary to remove 2,4-D and other contaminants from water to ensure quality standards.There are several methodologies used topur if water contaminated with emerging contaminants, such as photocatalytic oxidation (GIRI et al., 2010; LEE et al., 2015;), electrocoagulation (KAMARAJ et al. ,2014; KAMARAJ et al., 2015) Fenton degradation (CHEN et al., 2015), biodegradation (FERREIRA-GUEDES; MENDES; LEITÃO, 2012) and the adsorption process in which activated charcoal can be used (COELHO et al, 2019;WANG et al., 2020).

The use of activated charcoal in the water purification process is widespread worldwide due to its surface area and porous structure, functional groups, chemical properties, surface texture, and other characteristics importantfor processes such as adsorption.

In addition, it is important to emphasize that the activated charcoal production process can improve these characteristics even more (ALVES et al., 2019).

For the production of activated charcoal, the rawmaterial must be rich in carbonaceouscontent, such as wood and agro-industrial waste (CHOI et al., 2009). Activated charcoal lproduced from biological raw material is called a biosorbent (CUSÍOLI et al., 2019) which can be a good alternative due to its low costs of application. Besides, rice husk and cereal residues can be used for that purpose, since they turn into activated charcoal after processing (BOONAMNUAYVIRAYA et al., 2004; SATARI; KARIMI, 2018).

The number of toxic residues of agricultural, industrial, or domestic origin used in the environment with out proper treatment has been increasing exponentially. As a response, the use of bioassays to monitor toxicological effects on living organisms has been explored (BADERNA et al., 2011). To carry out bioassays, organisms that are bioindicators of environmental pollution are used.They can be species or communities, such as animals, plants, and microorganisms, which can detect the presence of toxic substances in the environment (HOLT; MILLER, 2011).

Plants are excellent indicators of genetic damage when exposed to chemical products, and tests that make use of them are simple and inexpensive (GRANT, 1999; MONTEIRO et al., 2007). For instance, Lactuca sativa L., popularly known as lettuce, has several advantages. It is used instudies for toxicity analysis, due to rapid germination, uniformity, and sensitivity (TIGRE et al., 2012), in addition to stable andwell-defined cytogenetic characteristics, such as large chromosomes in reduced number with karyotypic characteristics that facilitate a microscopic view of the chromosomes allowing a clear assessment of their alterations (SOUZA et al., 2009, HOU et al., 2014; PALMIERI et al., 2014; ARAGÃO et al., 2015; WANG et al., 2016; CARVALHO et al., 2019; VIEIRA et al., 2022).

There are studies on the removal of 2,4D, but none of them verified the toxicity oftreated water. This work, in turn, aimed to study the use of green coconut activated charcoal as an adsorbent for removing 2,4-D from water; verify the efficiency of Lactuca sativa L. as a bioindicator; and performcy to genetic analysis of the a forementioned contaminant.

Materials and methods

Preparation of solutions for the germination test

First, 2,4-D herbicide solutions (Sigma –Aldrich PA > 98%) were prepared at 2, 5, 10, and 20 mg/L concentrations. The solutions used for the germination test were: a) pure water (PW), b) water contaminated with 2,4-D (CW) and c) treated water (TW). To obtain the treated water sample, water was experimentally contaminated with different concentrations. Then, it was passed through a gravitational filter with green coconut-activatedcharcoal.

The solutions were analyzed with aspectro photometer (HACHDR5000) at a wavelength of 230 nm, before and after filtration.

Preparation of the gravitational filter

The gravitational filter was prepared with the aid of hermetic support as a container, provided by Carbontec®, a company based in Maringá, state of Paraná, Brazil (Purific - Brazil). Approximately 140 g of activated charcoal purchased from the company Bahia Carbon was added to the hermetic support, according to the size and maximum capacity.At first, about 20 L of deionized water was passed through the filter, so that the color would not interferewith the germination analysis. Rightafter that, the contaminated water (CW) was passed through the filter in continuous flow, and, after filtration, treated water (TW) was obtained. These steps were performed separately for all concentrations of the contaminant (SHIMABUKU et al., 2016).

Preparation of the germination test

The germination test was performed to verify the effect of solutions (a), (b), and (c) as described in item 2.1. Seeds of Lactuca sativa L. (TopSeed®) were used as bioindicators. For each solution, 100 seeds were used. All tests were performed in triplicate.We used germination paper (J. Prolab®), which was submerged in solutions (a, b, and c) for 24 hours. The seeds were sown on moistened paper and kept in an oven for 7 days at a temperature of 20ºC ± 1ºC. After this period, normal, abnormal, and dead seedlings were counted, and the proportions of normal seedlings per treatment were calculated. Regarding the classification of the seedlings, normal ones are understood as those that present all their essential structures, whereas the abnormal ones have defects in some parts and have no potential to develop (BRASIL, 2009).

Cytogenetic analysis

Seeds of *Lactuca sativa L.* were sown on Petri dishes and germination paper moistened with 5 mL of the respective solutions and remained in an oven for 48 hoursat 20ºC ± 1ºC. The methodology used for preparing the slides was that by Freitas *et al.* (2016) with modifications. The roots used for the cytogenetic analysis were collected and fixed into a solution of ethanol and acetic acid (3:1) for 24 hours. To prepare the slide, the meristematic region was cut and boiled in a 2% acetic or ceinsolution (Dinâmica®) transferred to the slide, covered with a cover slip, and care fully crushed over a drop of 2% acetic orcein solution. The slides were analyzed under an optical light microscope. There were 1,000 cells per slide and 3 slides per sample, witha total of 3,000 cells per sample.

The analyzed parameters were calculated by Çildirand Liman (2020). The Mitotic Index (MI) was calculated as the number of dividing cells divided by the total number of observed cells x 100. Chromosomal aberrations (CA) were replaced as the total number of cells with AC divided by the total number of observed cells x 100. After viewing under an optical microscope, the slides were viewed under a photographic microscope to capture images of the cell cycle and the chromosomal aberrations found.

Statistical analysis

The normality and homogeneity of variances were verified by using Shapiro-Wilk and Bartletttests respectively. As the germination data did not show any of these characteristics, they were transformed using the natural log of the proportion of normal seedlings, divided by the subtraction of the proportion of normal seedlings from one unit (*logito*) (Eq.1).

$$Logito = \ln\left(\frac{p}{1-p}\right) \quad \text{(Eq.1)}$$

Where p is the proportion of normal seedlings. Initially, normality and homogeneity of variances were verified by using Shapiro-Wilk and Bartlett tests respectively. As the germination data did not show any of these characteristics, they were transformed using the natural log of the proportion of normal seedlings, divided by the subtraction of the proportion of normal seedlings from one unit

For the genetic data, normality and homogeneity of variances were verified using Shapiro-Wilk and Bartletttests, respectively. As the MI and CW data did not show normality or homogeneity of variances, generalized linear models with gamma distributionand logarithmic link function were fitted for each variable, considering water and herbicide as factors. Fit quality was initially addressed by analyzing the deviations by degrees of free demand, later, by the standardized Pearson residuals graphs (NELDER; WEDDERBURN, 1972).

Results and discussion

Table 1 shows the results of the germination test for samples of pure, contaminated, and treated water.

Table 1. Mean and standard deviation of the proportions of germinated seeds according tothewater directors

Water sample	Mean and standard deviation
Pure	0.9216 ± 0.027A
Treated	0.8966 ± 0.031B
Contaminated	0 ± 0C

Means followed by the same letter do not differ from Tukey's test ($p<0.05$). Source: Own authorship (2023)

According to Table 1, regarding the germination test, there was no interaction between the two factors, namely water treatment and herbicide concentration (p=0.1333). There was a main effect to f water (p=0.0443), and no main effect oft heherbicide (p=0.8544). All water samples differed from each other according to Tukey's test

($p<0.05$). Pure water had the highest average proportion of seedlings with hall the irnormal structures, where as contaminated water did not show any normal seedlings, as root growth was inhibited at all concentrations, making them normal. The percentage of germination of the sample with treated water (89.6%) using green coconut activated charcoal differed statistically from the percentage of germination of the sample with pure water (92%).

This suggests that there may have been a fact or that influenced the process of water treatment, causing some residual contaminants to remaineven after the adsorption process. Dabrowski et al. (2005) listed some factors that can influence the process of water treatment by activated charcoal, such as the type of activated charcoal precursor (wood, petroleum residues, bituminous coal, lignite, between others), aqueous solubility of the compound and availability of oxygen in thes olution.

Akzo and Kabasakal (2004) analyzed the influence of temperature on adsorption, and the results showed that higher adsorption of 2,4-D occurs thigher temperatures. Thus, the water treatment process can be affected, and its results can be altered due to these parameters. This possibly explains the statistical differencein germination percentage between treated water and pure water samples.

Table 2. Mean and standard deviation of the mitotic index (MI) for all samples of *Lactuca sativa L.*

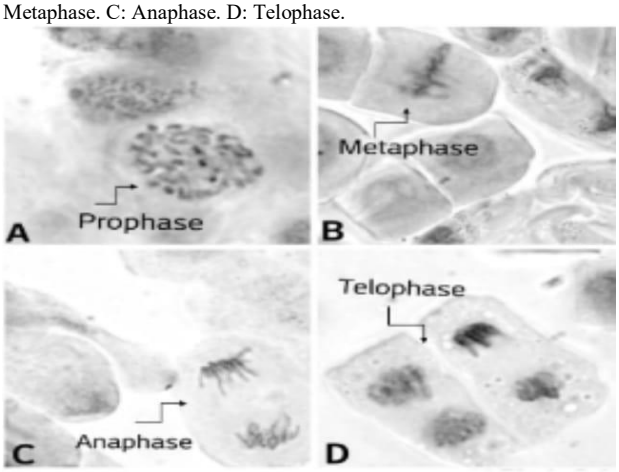
Samples	Herbicide Solution			
	2mg.L^{-1}	5mg.L^{-1}	10mg.L^{-1}	20mg.L^{-1}
P	11.20±0.36Aa	11.47±0.42Aa	11.47±0.40Aa	11.50±0.20Aa
T	10.9±0.09Aa	10.83±0.06Aa	10.87±0.12Aa	9.98±1.01Aa
C	7.79±0.38Ab	7.06±0.02Bb	6.96±0.07Bb	6.81±0.04Bb

The uppercase letters in the rows and lowerca seletters in the columnsdo not differ statistically by Tukey's test ($p<0.05$). (P = pure; T = treated; C = contaminated). Source: own authorship (2023).

For the Mitotic Index (MI), which corresponds to the total number of dividing cells during the cell cycle (Figure 1), there was an interaction between the factors of water treatment and herbicide concentration ($p=0.001$). There was no statistical difference between the 2,4-D concentrations for the pure and treated water samples since the average betweenhese two parameters was 11.41 and 10.64 respectively. As for contaminated water at a concentrationf 2 mg/L of 2,4-D, presented a statistically higher mean (7.79) than the other concentrations (7.06, 6.96, and 6.81) according to Tukey's test ($p<0.05$) (Table 2). For all 2,4-D concentrations tested, treated and pure water has statistically higher MI means (11.41 and 10.64) than contaminated water (7.15).

The 2,4-D showed totoxic effect for *L. sativa L.* when in higher concentrations (10 and 20 mg L). Thus, the sample with water contaminated with different concentrations of 2,4-D showed lower MI, respectively 7.79, 7.06, 6.96, and 6.81, about the indices in the samples with pure water, where the results were: 11.20, 11.47, 11.47 and 11.50, and treated (10.90, 10.83, 10.87, 9.98). For samples with treated water whose average between the four concentrations was 10.64, the MI values did not differ statistically about the pure water sample (average of 11.41), thus evidencing the efficiency in the treatment process, and samples with contaminated water were superior (mean MI of 7.15), regardless of concentration (Figure 1).

Figure 1. Phases of Mitosis in *L. sativa* L in pure water. A: Prophase. B: Metaphase. C: Anaphase. D: Telophase.



Source: Own authorship (2023)

As discussed bove, even if contaminant residues remained in the water (Table 2), they were not enough to affect themitotic index of the seeds. Themitotic index can assess the cytotoxicity of several agents (FERNANDES; MAZZEO; MARIN-MORALES, 2007) such as 2,4-D, and is indicative of environmental toxicity. Compounds that can interfere with the metabolism of plants represent a dangerto human health, and when present in water, even in small amounts, they are mutagenic and can cause birth defects (PATEL et al., 2019). Many toxic compounds can affect DNA and cause mutations (KLAUNIG; KAMENDULIS; HOCEVAR, 2010). The mixture of toxic compounds found in industrial effluents may be related to carcinogenicity (OHE; WATANABE; WAKABAYASHI, 2004; RICE et al., 2018). Table 3 shows the values obtained for Chromosomal Abnormalities (CA) in samples treated with 2,4-D.

Table 3. Means and Standard Deviation of Chromosomal Abnormalities (CA).

Samples	Herbicide Solution			
	2mg.L^{-1}	5mg.L^{-1}	10mg.L^{-1}	20mg.L^{-1}
P	0.10±0.10Aa	0.10±0.17Aa	0.10±>0.001Ab	0.10±0.10Ab
T	0.30±0.20Aa	0.23±0.15Aa	0.20±0.10Ab	0.30±0.10Ab
C	0.47±0.15Ca	0.60±0.10Ba	1.00±0.10Aba	1.10±0.20Aa

The saupperca seletters in the rows and lower case letters in the columns do not differ statistically by Tukey's test ($p<0.05$). (P = pure; T = treated; C = contaminated). Source:Oown authorship (2023)

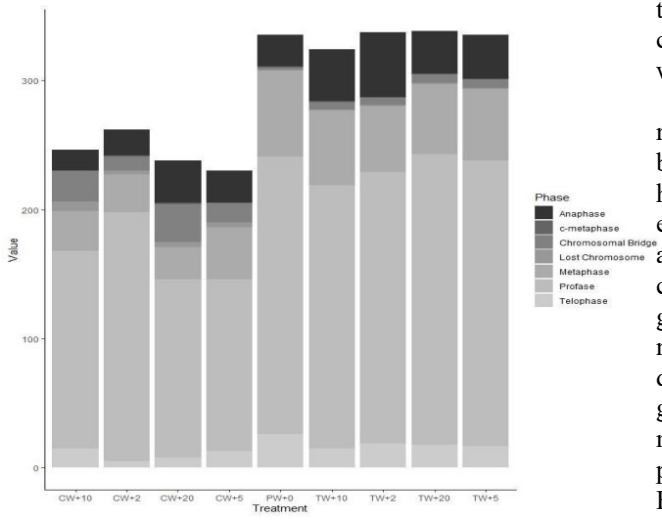
For Chromosomal Aberrations (CA) there was interaction between water treatmentand herbicide concentration ($p=0.0062$). AC gradually increased according to exposure to 2,4-D concentrations in contaminated water, values ranged from 0.47 to 1.10 according to the increase in herbicide concentration (table). The AC, as well as the IM, varied according to the concentrations. At higher concentrations of 2,4-D (10 and 20 mg/L), CA rates also increased in treated (0.20 and 0.30) and contaminated (1.00 and 1.10) water samples,

demonstrating a concentration-dependent positive effect, while at lower concentrations (2 and 5 mg/L), there was no signify cant difference between CA rates.

Figures 2 and 3 list the cell cyclephases and chromosomal berrations found for each sample and 2,4-D concentrations. We can observe that the prophase phasesod out, being found more frequently, followed by metaphase, anaphase, and, finally, telophase. Regarding the analysis of chromosomal berrations, chromosome bridges in anaphase were more frequent, followed by chromosomes lost in metaphase and, finally, c-metaphases.

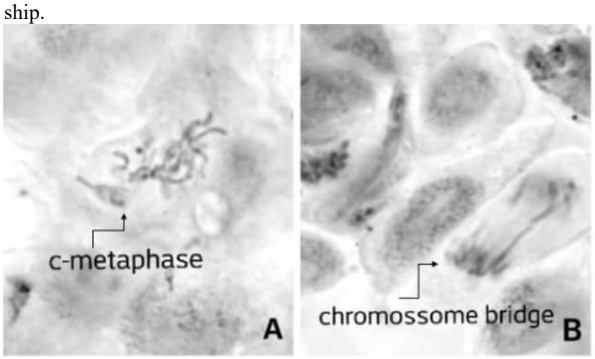
Chromosomal aberrations (Figure 3) correspond to abnormalities found during the cell cycle, such as c-metaphases, chromosomal bridges, chromosome loss, and others. In this study, we detected 3 of them, namely-metaphase and chromo some loss, which indicate aneugenic damage, and chromosomal bridges, due to clastogenic effects. The genotoxic potential of 2,4-D has been identified in different plant species, whose alterations induced by this herbicide involve chromosomal fragmentation, bridges, chromosomal adhesion, lagging chromosomes, micronucleus, and in addition, strandbreaks in DNA (ENAN, 2009).

Figure 2. Grouped graph of all cell cyclephases and chromosomal aberrations found.



Source: Own author ship (2023)

Figure 3. Chromosomal abnormalities found. A:C-metaphase, B: anaphase– an arrow indicatesa chromosomal bridge. Source: own author ship.



Source: Own authorship (2023)

The effects of 2,4-D on seeds of *L. sativa L*. are still unknown, but its seeds treated with different concentrations of the herbicide glyphosate demonstrated chromosomal anomalies such as chromosomal ossand stickychromo some, anaphase and telophase with bridges, multipolar anaphase, and C-metaphase, in addition to the formation of micronuclei (VIEIRA et al., 2022).

Plants have been used as bioindicators of environmental pollution for a long time, as they of ferthe assessment of toxicity and mutagenicity present in the environment (SANDALIO et al., 2001). Chromosomal aberrations determine the genotoxicity of compounds or substances, where as the mitotic index is used to determine cytotoxicity. The mechanisms of action of the substances can be clastogenic when they involve breaking chromosomes and aneugenic when there are chromosomally and spindle alterations (LEME; MARIN-MORALES, 2009, VIEIRA SILVEIRA, 2018; VIEIRA *et al*., 2022).

Activated charcoal is widely used to remove pollutants not only from waste water streams but also from drinking water sources, such as ground water, rivers, and lakes (Crini et al., 2019). Brito et al. (2020) used coconut shell and babassu endocarp-activated bio charcoal, and achieved a 2,4-D removal index of 97% and 99%, respectively. These results are similar to that of our study, in which, through the use of bioassays with *L. sativa L.,* the water sample treated with green coconut activated charco al showed results very similar to those of the pure water samples.

In the same way that the 2,4-D herbicide caused root growth inhibition in *L.sativa L.* seedlings, the study by Brito et al., (2017) tested two bases of the glyphosate herbicide (Roundup® and Glyphosate AKB 480 ®) to evaluate the effects on lettuce seed germination. The authors detected are duction of the root system at all concentrations tested. Reduced root growth affects the growth of an entire seedling by restricting water and nutrient uptake. The phytotoxic effects of 2,4-D are directly related to these restrictions imposed on seedling growth,and lead to inhibition of enzyme activity and membrane instability with detrimental changes in the physiology of lettuce sedgings (LAMHAMDI et al., 2011). For contaminated water, there was no normal seedling in any of the repetitions, as there was no proportional grow thand development of the root system.

The 2,4-D is harmful to the environment, for has phytotoxic, cytotoxic, and genotoxic effects on several plants. The results obtained in our research corroborate studies by Okzul *et al.,* (2016) where Allium cepa L. bulb roots were exposed to different concentrations of 2,4-D at a higher concentration, which was 4.02 mg/L. The phytotoxic and cytotoxic effects of 2,4-D led to root growth inhibition and a decreased mitotic indexin addition to chromosomal aberrations which was the case in this study. Both are closely related since plant growth demands cell proliferation (HARASHIMA; SCHINITTGER, 2010).

The results of our study are in linewith other published studies that addresssing these of vegetables as bioindicators of environmental pollution, both for pollutants in general and for pesticides, oils, drugs, and dyes. In the study by Pawlowski et al., (2013) whose dan essential oil from Schinus Lentisci folius March., in

bioassays with *L. sativa L.* and *Allium cepa L.*, both species had a decrease in their MI by 25.14% and 19.35%, respectively. There was also induction of aneugenic and clastogenic effects in both of them. Alves *et al*., (2018) studied the effect of two phenolic compounds (Timol and Carvacrol) on *L. sativa L.* seeds, and both showed a toxic effect. Carvacrol showed a genotoxic effect on *L. sativa L*., with chromosomal aberrations, effects that are similar to those caused by 2,4-D.

About humans, the presence of the 2,4-D poses heals risks. Some studies have suggested that exposure to 2,4-D is related to the risk of developing Parkinson's (Tanner *et al.,* 2009), as well as soft sarcoma, non-Hodgkin's, blad Behandlung cancers in farmers and workers exposed to 2,4-D during manufacturing and handling processes (GOODMAN; LOFTUS; ZIL, 2017; BOERS et al., 2010; KOUTROS et al., 2016; COGGON et al., 2015; AYLWARD, HAYS, 2015). Inlight of the foregoing, removing 2,4-D and other pollutants from water is necessary to maintain its quality standards for human, animal, and vegetable consumption.

With all this, the contribution of the study was to point out important results, addressing the removal of 2,4-D from water, which is an environmental and public health concern and which has been of great concern worldwide. Contamination of water by herbicides can have adverse effects on human health and aquatic ecosystems. The adsorption process with green coconut activated carbon together with the test of *L sativa* L. seeds was effective, this can contribute to the improvement of water quality and the reduction of the negative impacts of this contaminant and also give a better destination to the waste agroindustrial. Drinking water is a fundamental human right, and ensuring the supply of clean and safe water is essential for the health and well-being of the population.

Conclusion

The use of green coconut activated charcoal proved to be efficient in the treatment of water contaminated with different concentrations of 2,4-D, since the results of the germination bioassays and cytogenetically were very similar. Seeds of *Lactuca sativa* L. showed to be sensitive inthe detection of 2,4-D in water, which makes them a good indicator for this compound in an aqueous medium. Herbicide 2,4-D caused phytotoxic damage to *Lactuca sativa* L. to see dings, inhibiting the growthand development of their root system at all concentrations (2, 5, 10 e 20 mg/L). Regarding the cytogenetic analysis, the reduction of the MI (11,41 of pure water, 10,65 treated water, to 7,16 of contaminated water) and CA rates increased in treated (0.20 and 0.30) and contaminated (1.00 and 1.10) water samples indicated cytotoxicity and genotoxicity of 2,4-D, by the concentrations used, which did not occur significantly in treated water. Due to the toxic potential of 2,4-D, it is crucial to remove it from water, for it interferes with the metabolism of several organisms. Therefore, the use of green coconut-activatedcharcoal is an excellent alternative to address thisuse.

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