Do cancer cells in human and meristematic cells in plant exhibit similar responses toward plant extracts with cytotoxic activities?

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Abstract We examined the effect of water extracts of *Persea americana* fruit, and of the leaves of *Tabernamontana divericata*, *Nerium oleander* and *Annona cherimolia* (positive control) on *Vicia faba* root cells. We had confirmed in our previously published data the cytotoxicity of these plant extracts on four human cancer cell lines: liver (HepG-2), lung (A549), colon (HT-29) and breast (MCF-7). *Vicia faba* roots were soaked in plant extracts at dilutions of 100, 1,250, 2,500, 5,000, 10,000, 20,000 ppm for 4 and 24 h. All treatments resulted in a significant reduction in the mitotic index in a dose dependant manner. Root cells treated with *T. divericata*, *N. oleander* and *A. cherimolia* exhibited a decrease in prophase cell percentage, increase in micronuclei and chromosomal abnormalities as concentration increased. The *P. americana* treatment showed the highest cytotoxic effect on cancer cells, prophase cell percentage increased linearly with the applied concentration and no micronuclei were detected. This study shows that root tip assay of beans can be used in initial screening for new plant extracts to validate their use as candidates for containing active cytotoxic agents

against malignant cells. This will greatly help in exploring new plant extracts as drugs for cancer treatment.

Keywords *Annona cherimolia* micronuclei ·
Nerium oleander · *Persea americana* ·
Tabernamontana divericata ·
Vicia faba root assay

Introduction

Nowadays the significance of plants as pharmaceutical sources is extremely highlighted, where many of them have always been used as mere traditional or folk remedies (Tiwari 2008). Many studies are focused on plants as accessible sources of food supplements (Abraham et al. 2012; Adebajo et al. 2012) to increase immunity (Bayrami and Boskabady 2013; Benmebarek et al. 2013; Buapool et al. 2013) wound healing (Chandra et al. 2013) and as cancer preventive (Bhagat et al. 2012). Extensive research is continuously carried out to explore some of these plants with a variety of pharmacological active compounds (Am et al. 2013). The priority had been given to plant extracts which can antagonize, reduce or modify the processes of mutagenesis and carcinogenesis. A preventive approach in this connection can provide the organism at risk with more resistance toward unavoidable environmental hazards by adding phytochemopreventive supplements to its diet (Haniadka et al. 2013).

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Table 1 The effect of plant extracts on the mitotic index of *Vicia faba* L.

Plant extract		<i>Persea americana</i>			<i>Tabernaemontana divaricata</i>			<i>Nerium oleander</i>			<i>Annona cherimolia</i>		
Time	Conc. ppm	Number of observed cells	MI (X ± SE) (%)	Number of observed cells	MI (X ± SE) (%)	Number of observed cells	MI (X ± SE) (%)	Number of observed cells	MI (X ± SE) (%)	Number of observed cells	MI (X ± SE) (%)	Number of observed cells	MI (X ± SE) (%)
4 h	Control	3,006						3.16 ± 0.24					
	100	3,360	2.98 ± 0.57	3,035	2.96 ± 0.26	3,057	3.37 ± 0.42	3,078	3.44 ± 0.55				
	1,250	4,200	2.86 ± 0.39	3,657	2.73 ± 0.52	4,560	3.18 ± 0.43	3,850	3.17 ± 0.43				
	2,500	4,117	2.77 ± 0.49	3,887	2.50 ± 0.50	4,344	3.04 ± 0.44	4,077	2.87 ± 0.38				
	5,000	3,640	1.92 ± 0.68	3,156	2.09 ± 0.5	3,005	2.36 ± 0.47	4,428	2.14 ± 0.55				
	10,000	4,200	1.50 ± 0.61*	3,078	1.79 ± 0.52*	3,038	2.17 ± 0.6	3,630	1.63 ± 0.81*				
24 h	20,000	4,944	1.03 ± 0.14**	3,014	1.56 ± 0.19**	3,015	2.056 ± 0.66	3,376	1.48 ± 0.73*				
	Control	3,017				8.30 ± 0.6							
	100	3,516	8.08 ± 0.68	3,004	8.00 ± 0.56	3,151	8 ± 0.66	3,033	8.08 ± 0.70				
	1,250	3,450	7.68 ± 0.90	3,076	6.83 ± 0.94	3,630	7.69 ± 0.58	4,015	6.95 ± 0.55				
	2,500	4,322	6.94 ± 0.77	3,089	6.31 ± 0.90	4,070	6.95 ± 0.65	4,115	6.32 ± 0.86				
	5,000	4,200	4.29 ± 0.33**	3,014	4.90 ± 1.42*	3,084	4.7 ± 1.33*	3,321	4.67 ± 0.33**				
	10,000	4,023	3.11 ± 0.38**	3,020	4.00 ± 0.76**	3,008	4.22 ± 0.34**	3,130	3.80 ± 0.56**				
	20,000	3,697	2.11 ± 0.24**	3,009	3.72 ± 0.50**	3,040	3.95 ± 0.47**	3,900	3.08 ± 0.41**				

* $P < 0.05$; ** $P < 0.001$ as compared to the untreated control plants

Table 2 Effect of plant extracts on micronucleus formation rate in *Vicia faba* root tip cells

Time	Conc. ppm	Micronuclei formation rate (%)			
		<i>Persea americana</i>	<i>Tabernamontana divaricata</i>	<i>Nerium oleander</i>	<i>Annona cherimolia</i>
4 h	Control	–	–	–	–
	100	–	–	–	1.68
	1,250	–	2.08	1.86	1.86
	2,500	–	2.41	1.95	2.12
	5,000	–	2.92	2.07	2.83
	10,000	–	3.03	3.47	3.23
	20,000	–	3.86	4.03	3.40
24 h	Control	–	–	–	–
	100	–	1.69	1.81	1.79
	1,250	–	1.77	2.78	1.93
	2,500	–	2.68	3.32	2.03
	5,000	–	3.11	4.22	2.45
	10,000	–	4.41	7.60	3.37
	20,000	–	4.46	7.80	3.80

Fig. 1 Effect of water extracts used on micronuclei formation rate. micronuclei were linearly increasing in a dose dependant manner. No micronuclei were detected in control plants, those treated with all concentrations of *Persea americana* and plants treated for 4 h with 100 ppm of *T. divericata* and *N. oleander*. The number of micronuclei was **a** One micronucleus per cells

was detected in plants treated with all other concentrations of *T. divericata* and *N. oleander* extracts, **b** two micronuclei per cells were detected and **c** nuclear bud were detected in plants treated with all concentrations of *A. cherimolia* water extract for 4 and 24 h

Table 3 Frequency (%) of abnormal cells at different mitotic phases after treating *Vicia faba* root tips with *Persea americana* extract for 4 and 24 h

Duration	Conc. Ppm	Micronucleus (%)	Prophase (%)	C-m (%)	Star (%)	Break (%)	Stickiness (%)	Disturbed (%)	Metaphase Laggards (%)	Total (%)	Bridge (%)	Break (%)	Laggard (%)	Disturbed (%)
4 h	Cont.	–	–	–	–	–	–	4.50	–	4.50	–	–	–	4.30
	100	–	–	–	–	–	–	4.00	–	4.00	–	–	–	4.00
	1,250	–	–	3.45	–	–	–	6.90	–	10.35	3.57	–	–	3.57
	2,500	–	–	3.33	–	–	–	6.67	–	10.00	6.67	–	–	–
	5,000	–	3.13	–	–	–	5.00	5.00	–	10.00	5.56	–	–	–
	10,000	–	3.45	5.00	–	–	5.26	5.53	–	15.79	6.67	–	–	–
24 h	20,000	–	4.55	5.88	–	–	5.88	11.76	–	23.52	8.33	–	8.33	–
	Cont.	–	–	–	–	–	–	3.30	–	3.30	–	–	–	2.90
	100	–	–	1.43	–	–	–	2.86	–	4.20	–	–	2.63	2.63
	1,250	–	–	3.13	–	1.56	–	3.13	–	7.81	4.29	–	2.86	–
	2,500	–	1.94	–	1.30	1.30	2.60	3.90	–	9.10	4.41	1.47	1.47	–
	5,000	–	2.00	5.40	2.70	4.00	5.40	8.11	–	21.61	4.65	–	2.33	2.33
	10,000	–	2.74	12.00	–	–	8.00	16.0	4.00	44.00	11.11	3.70	3.7	7.41
	20,000	–	9.09	18.75	–	–	12.5	18.75	6.25	56.25	17.65	–	5.88	11.76

Fig. 2 Chromosomal abnormalities induced upon treatments with the water extracts under study. Representative micrograph pictures showing the most common abnormalities. **a** Chromosomal stickiness is commonly observed in plants treated with the

highest concentrations of *P. americana*. **b** disturbed metaphase and **c** chromosomal laggards are most common in plants treated with *N. oleander*, *T. divericata* and *A. cherimolia*

Potential anticancer activity might not result from cytotoxic or induction of apoptosis in the treated cells but the antiproliferative effects of the extracts could be mediated through cell cycle arrest in the S-phase (González-Sarriás et al. 2012). Thus, mitotic and replication indexes (MI and RI, respectively) are used as biomarkers for an adequate cell proliferation (Eroğlu et al. 2010).

To evaluate the potential use of a plant extract as a cytotoxic or anti-proliferating agent, a wide range of screening procedures are available, yet most of which are costly and complicated. Dependence on the use of higher plants as test assays has been integrated in risk assessment for the detection of many environmental mutagens as being very simple, quick, inexpensive, efficient and reliable (Rosa et al. 2003; Panda et al. 2011). Plant systems are characterized by many genetic end points to measure, such as the frequency of chromosomal aberrations, MN rate, and MI frequency (Beraud et al. 2007). In this respect, the root tip

meristems of *Vicia faba* (broad beans) have been used as a pioneer cytogenetic material for the detection of genotoxicity in many studies (Ma et al. 2005; Dong and Zhang 2010). This assay had also been used since the 1920s as a standard test for the chemical screening and in situ monitoring for genotoxicity at the environmental level (Ma et al. 1995). Although, this bioassay was validated by the International Programme on Chemical Safety (IPCS, WHO) and the United Nations Environment Program (UNEP), it had been sparingly used for screening natural plant extracts with possible potential for cytotoxic and mitodepressive properties against cancer cell lines.

Thus, the objective of this study was to determine if the classical *V. faba* root tip assay can accurately be used for bioscreening of plant extracts with cytotoxic/mitodepressive activities against cancer cells. For this aim, different dilutions of water extracts of *Persea americana* fruit, and *Tabernamontana divericata*, *Nerium oleander* and *Annona cherimolia* leaves were

Fig. 3 Effect of water extracts of *P. americana*, *T. divericata*, *N. oleander* and *A. cherimolia* on different mitotic phases of treated *V. faba* root tip cells for 4 and 24 h. **a–h** Statistical analyses of the effect of the water extracts for **a** 4 h and **b** 24 h treatments with *P. americana*. **c** 4 h and **d** 24 h treatments with *T. divericata*. **e** 4 h and **f** 24 h treatments with *N. oleander*. **g** 4 h and **h** 24 h treatments with *A. cherimolia*

used for investigating their effects on the frequencies of MI, MN, CA in *V. faba* root- tip cells. These extracts have been tested previously by us (El-Hallouty et al. 2012) on several human cancer cell lines. Thus, we intended in this work to compare between the previously obtained results on using human and those recorded herein with plant cells as test objects. In case that similar trend is shown, this would then show new insights for using plant root tip assays more seriously to explore new plants for putative anticancer therapies.

Materials and methods

Plant materials

The plant materials used were the green leaves of *Annona cherimolia*, *Tabernamontana divericata*, *Nerium oleander* and the fruit of *Persea americana*. These samples were collected from El Orman Botanical Garden (Giza, Egypt). The plants were identified by botanists in the herbarium of the Botany Department, Faculty of Science, Ain Shams University. Voucher specimens were kept in the herbarium, department of Botany, Faculty of Science, Ain Shams University, under the name of Noha-Dina 2009. Leaves were collected at approximately similar age (the third fully expanded leaves from the top of each branch) and fully ripened dry fruits of *P. americana* were used. Seeds of *V. faba* (cultivar: Windsor white), used as a test object, were kindly provided by the Agriculture Research Centre, Ministry of Agriculture, Giza, Egypt.

Preparation of extracts

Water extracts of the samples under investigation were prepared as follows: two grams of fresh material was ground and dissolved in 100 ml of 90 °C distilled water and then incubated at the same temperature for 15 min, cooled, filtered and used as a stock. Water extracts were prepared and used the

same day of collection to avoid any change in the sample constituents. Distilled water was used as a control and the whole experiment was carried out at room temperature.

Root tip preparations and treatment

Dry seeds of Windsor white *V. faba* seeds were abundantly rinsed with distilled water and then soaked in distilled water for 24 h. Germinating seedlings were kept at 25 °C on moist gauze until their primary roots were 1–2 cm in length (Cotelle et al. 1999). Root tips were exposed for 4 and 24 h to different dilutions (100, 1,250, 2,500, 5,000, 10,000, 20,000 ppm) of the water extracts. Distilled water was used as a negative control. The water extract of *A. cherimolia* (a potent cytotoxic against all cultured human cancer cell lines) was used as a positive control following the same concentration series. All treatments were done in triplicates and kept at temperature of 25 ± 2 °C.

Cytological study and slide preparation

Root-tips were cut directly into Carnoy's solution [absolute alcohol: glacial acetic acid (3:1)] for 24 h then hydrolyzed in 1 N analar HCl at 58–60 °C for 10 min (Qian 2004). Root tips—3 mm long—were squashed and stained using Leuco-basic Fuchsin technique (Darlington and La-Cour 1976). Light green dye (0.3 %) was used for background staining of the cytoplasm. Root tips were squashed in 45 % acetic acid. Dehydration was done using ascending series of ethyl alcohols; 30, 50, 70, 96 %, absolute alcohol; absolute alcohol: xylene (1:1) and xylene, keeping root tips for 5 min in each concentration. Preparations were mounted in Canada balsam (Sigma-Aldrich, Munich, Germany) and placed at 45 °C in the oven (until completely dry). Root tips were examined for micronuclei frequencies and other abnormalities at 4,000× magnification using a Leica light microscope (Wetzlar, Germany). The photomicrographs were taken from the prepared slides using a digital camera (8Mp; Sony, Tokyo, Japan).

Mitotic indices (MI) (%) were calculated using the following formula:

$$\text{Mitotic index (MI)(\%)} = \frac{\text{Number of dividing cells}}{\text{Total cells examined}} \times 100$$

Statistical analysis

Data shown are the means and standard errors of three or more independent experiments. Statistical comparisons between groups were made by Student's *t* test using Microsoft excel program, and a *P* value <0.05 considered to be statistically significant.

Results

The effect of plant extracts on mitotic indices

As shown in Table 1, we observed a decrease in the mitotic indices of root tip cells of *V. faba* in a dose-dependant manner in all plant extracts used. Differences in mitotic indices between the treated plants and the untreated control were significant at the highest concentrations of 10,000 and 20,000 ppm, applied for 4 h, for all plant extracts except those of *N. oleander*. On exposure of the root tip cells to the experimental extracts for 24 h, the mitotic indices for all samples were significantly reduced than those of the control at concentrations of 5,000, 10,000 and 20,000 ppm.

Micronuclei formation rate of *V. faba* root tip cells

The water extract of *N. oleander* exhibited the highest induction rate of micronuclei formation in *V. faba* root tip cells followed by those of *T. divericata* and *A. cherimolia*, respectively (Table 2). The number of micronuclei remained one per cell in plants treated with the water extract of *T. divericata* and *N. oleander* (Fig. 1a). In plants treated with higher concentrations (10,000, 20,000 ppm) of *A. cherimolia* water extract, we observed more than one micronucleus per cell (Fig. 1b) with the formation of nuclear bud (Fig. 1c). Interestingly, no micronuclei were detected in the root cells of *V. faba* plants treated with all tested concentrations of *P. americana* either for 4 or 24 h (Table 2).

Chromosome aberration rate of *V. faba* root tip cells

All plant extracts tested were able to induce chromosomal abnormalities in a dose dependant manner as shown in Table 3. Root tip cells treated with the plant extract of *P. americana* exhibited the least chromosomal abnormalities as compared with the other plant

extracts used in this study. This result applies for both treatment durations used (4 or 24 h). The most common abnormalities were stickiness in plants treated with the water extract of *P. americana* fruit (Fig. 2a). Chromosome laggards (Fig. 2b) and disturbed metaphase chromosomes (Fig. 2c) were the most common abnormalities detected in plants treated with the leaf water extracts of *N. oleander*, *T. divericata* and *A. cherimolia*.

Percentage of different mitotic phases

As shown in Fig. 3, the percentage of prophase cells were decreasing in a dose dependant manner in all treatments used for 4 h and in plants treated with *N. oleander*, *T. divericata* and *A. cherimolia* for 24 h. On the other hand, the percentage of prophase cells was increasing linearly with the concentration applied in plants treated with *P. americana* for 24 h (Fig. 3b). The metaphase and ana-telophase percentages were increasing as well in all 4 and 24 h treatments except in plants treated with the water extract of *P. americana* fruit where these percentages exhibited a very slight decrease when compared with control plants (Table 4).

Discussion

Plant bioassays that measure mitotic cell cycle, micronuclei induction rate and the frequency of chromosomal aberrations are both time and cost effective. These tests are helpful in screening the bioactivity of plant extracts at large scale, particularly in areas with limited funds. They will also eliminate the hazards of using cultured human cells and live animals. Some studies showed that plant and animal cells exhibited similar responses towards treatments with bioactive compounds (Konuk et al. 2007). Plant assays are sensitive and had been used to determine the activity of complex mixtures since a long time ago (Rank and Nielsen 1993). However, plant bioassays are mostly used to measure the carcinogenicity or mutagenicity rather than the medicinal properties of tested material. Overall currently available data suggest that genotoxic carcinogens can be detected with intact plant assays (Turkoglu 2013). Thus, it is logic enough to predict that the same applies for detecting DNA protective compounds with intact plant assays as well.

Table 4 Effect of plant extracts on metaphase (%), anaphase (%) and abnormal mitosis in treated root tip cells of *Vicia faba* L.

Plant extract		<i>Persea americana</i>				<i>Tabernaemontana montana</i>				<i>Nerium oleander</i>				<i>Annona cherimolia</i>			
Time	Conc. ppm	Normal		Abnormal Mitosis (%)		Normal		Abnormal Mitosis (%)		Normal		Abnormal Mitosis (%)		Normal		Abnormal Mitosis (%)	
		Metaphase (%)	Anaphase (%)			Metaphase (%)	Anaphase (%)			Metaphase (%)	Anaphase (%)			Metaphase (%)	Anaphase (%)		
4 h	Control	26.40	23.58	1.88 ± 0.61		26.40	23.58	1.88 ± 0.61		26.40	23.58	1.88 ± 0.61		26.40	23.58	1.88 ± 0.61	
	100	25.00	25.00	3.00 ± 0.92		22.20	25.50	3.33 ± 0.59		25.2	25.2	1.94 ± 0.37		29.25	20.75	3.92 ± 0.60	
	1,250	24.17	23.33	4.17 ± 0.69		27.00	28.00	5.00 ± 1.46		27.59	22.76	4.14 ± 1.062		27.05	25.41	5.74 ± 1.85	
	2,500	26.32	26.32	4.39 ± 1.18		26.80	32.00	9.28 ± 3.60		30.6	21.64	6.00 ± 2.02		29.06	28.20	6.84 ± 2.43	
	5,000	28.57	25.71	5.71 ± 1.95		31.82	28.79	19.7 ± 1.28**		36.62	19.72	8.40 ± 2.90		36.84	25.26	8.40 ± 2.47*	
	10,000	30.16	23.80	7.94 ± 2.60*		38.46	27.27	32.73 ± 1.09**		42.42	18.18	16.67 ± 1.48**		39.00	23.73	16.95 ± 1.32**	
24 h	20,000	33.33	23.53	13.73 ± 1.35**		38.30	27.66	44.68 ± 0.86**		40.32	17.74	19.35 ± 0.77**		40.00	26.00	26.19 ± 1.4**	
	Control	24.30	27.50	1.60 ± 0.57		24.30	27.50	1.60 ± 0.57		24.3	27.5	1.60 ± 0.57		24.30	27.50	1.60 ± 0.18	
	100	24.65	26.76	2.46 ± 0.46		26.10	26.10	2.00 ± 0.51		26.6	28.2	1.96 ± 0.47		22.45	27.76	1.63 ± 0.143	
	1,250	24.15	26.42	3.77 ± 1.00		28.57	27.62	7.14 ± 2.23		29.03	26.17	4.30 ± 1.51		28.67	26.88	7.17 ± 3.03	
	2,500	25.67	22.67	5.00 ± 1.91		31.79	27.69	10.25 ± 2.82*		31.45	24.38	7.07 ± 1.89*		33.85	24.62	10.40 ± 3.38*	
	5,000	20.56	23.89	7.78 ± 2.66		33.60	26.80	24.16 ± 1.68**		36.55	19.31	13.79 ± 0.91**		45.16	17.42	23.23 ± 0.83**	
	10,000	20.00	21.60	16.00 ± 1.41**		35.80	26.70	37.5 ± 1.41**		40.94	19.69	23.62 ± 0.73**		41.18	18.49	36.13 ± 1.2**	
	20,000	20.51	21.79	24.36 ± 0.55**		37.50	28.60	50.00 ± 1.3**		44.17	18.33	35.00 ± 61**		47.50	19.17	45.83 ± 1.45**	

In this study, we intended to determine some parameters that a researcher should have in mind when screening for extracts with cytotoxic activity toward cancer cells by using plant cells in his initial screening. In our previous study (El-Hallouty et al. 2012), we screened 22 different plant extracts against four human cancer cell lines: liver (HepG-2), lung (A549), colon (HT-29) and breast (MCF-7) to determine their cytotoxic activities using MTT-assay. We found that the water extract of *P. americana* fruit resulted in more than 90 % mortality in all of the treated cancer cell lines used. Interestingly, this water extract was more effective than that of *Annona cherimolia* leaf extract, which is routinely used as a positive cytotoxic control for all of these cancer cell lines (El-Menshawhi et al. 2010). Our results also showed that *Tabernamontana divericata* extract resulted in 96.4 and 94.3 % mortality rate in liver and colon carcinoma, respectively. On the other hand, *N. oleander* leaf extract effect was moderate (82.4 % mortality) in lung carcinoma and its effect was low in other cell lines, but it is used herein for comparison.

At present, there are no published data assessing the effect of the four plant extracts used in this work on the mitotic index in *V. faba* root tips. We have noted a decrease in the mean mitotic index values in root-tips treated with *P. americana*, *T. divericata*, *N. oleander* and *A. cherimolia*, as compared with corresponding controls. This decrease was the most pronounced in case of the treatment with *P. americana* water extracts. The decrease in mitotic index indicated that the experimental material exhibited a mitodepressive effect which had been assumed to result from the inhibition of cells access to mitosis (Badr and Ibrahim 1987). Such an antimitotic effect is most likely attained by preventing DNA biosynthesis or/and microtubule formation (Yüzbaşıoğlu et al. 2003). This might be attributed to a slower progression of cells from S (DNA synthesis) phase to M (mitosis) phase of the cell cycle (Blakemore et al. 2013).

In the 4 h treatment, we observed that the percentage of different mitotic phases (prophase, metaphase, and ana-telophase) were more or less following the same trend, in response to treatments with the different dilutions of all plant extracts used in this study (Fig. 3a, c, g). For the 24 h treatment, the percentage of cells in prophase was progressively increased with increasing the dose rate of *P. americana* extract (Fig. 3b). In case of treatments with *T. divericata*, *N. oleander* and *A. cherimolia* extracts, on the other hand,

the percentage of prophase cells was decreasing in a dose dependant manner (Fig. 3d, f, h). However, more investigations are needed to elucidate the biochemical mechanisms involved in this respect.

In this study, we intended to test for the genotoxicity dose of the plant extracts under investigation, using the MN assays, in order to assess the safety of their possible use as therapeutic drugs in future work. The obtained results showed that the decrease in the mitotic index was associated with the formation of micronuclei (MN) in all treatments used except those with *P. americana* (Table 2). The increase in micronuclei formation was found to be statistically significant in the differently treated root-tips, as compared to the corresponding controls. Interestingly, the extract of *N. oleander* was the most effective with respect to micronuclei formation. The induction of MN has been used in many studies as an indicator of genotoxicity (Cavas and Ergene-Gozukara 2005). In this connection, the assessment of micronuclei is commonly used for evaluating structural and numerical chromosomal aberrations induced by clastogenic agents that cause chromosomal breaks and aneugenic agents that disturb microtubule (Bellini et al. 2006; Dufour et al. 2006; Benfenati et al. 2009). These abnormalities represent reflections of structural and/or numerical chromosomal aberrations arising during mitosis (Fenech et al. 1999).

Conclusions

Our study indicates that the reduction in the mitotic index alone is not a sufficient indicator to evaluate the potency of plant extract cytotoxicity against cancer cells. One should also have in mind, the percentage of mitotic phases, particularly the prophase, and the frequency of micronuclei formation (Abraham et al. 2012).

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