Effect of Chemical Mutagens (Sodium Azide and Diethyl Sulphate) on *Amaranthus caudatus* L. and *A. hypochondriacus* L. I-Vegetative Growth and Flowering

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ABSTRACT

The experiments were carried out in two successive seasons, 2001/2002 and 2002/2003, in the Flowers and Ornamental Plants Research Gardens, Faculty of Agriculture, Alexandria University, to study the effect of different concentrations of sodium azide (SA) and diethyl sulphate (DES) on the morphological characteristics of *Amaranthus caudatus* L. and *A. hypochondriacus* L. as well as on the possibility of mutations induction . The concentrations of the two used mutagens were: 0 (distilled water), 1000, 2000, 3000, 4000 and 5000 ppm. of each, SA and DES increased the seed germination percentage, plant height, number of branches per plant, stem diameter, number of leaves per plant, and leaf area in both seasons for *A. caudatus* and *A. hypochondriacus*. In *A. caudatus*, the concentrations of 3000 ppm. SA and 2000 ppm. DES increased the anthocyanin content in both seasons. The low concentrations up to 3000 ppm. SA and DES in *A. hypochondriacus* increased the total chlorophyll content. As for *A. caudatus*, the concentrations of 2000 ppm. SA and 1000 ppm. DES increased the fresh and dry weights in both seasons. In *A. hypochondriacus*, the concentrations of 3000 ppm. SA and 2000 ppm. DES increased the fresh and dry weights in both seasons. Concerning flowering in *A. caudatus and A. hypochondriacus,* the high concentration of 5000 ppm. SA and 5000 ppm. DES delayed the flowering in both seasons. The intermediate concentrations of SA and DES up to 4000 ppm. increased the number of inflorescences per plant, the inflorescence length and diameter in both seasons for *A. caudatus* and *A. hypochondriacus* .

Key words: chemical mutagen, SA, DES, Amaranthus caudatus, A. hypochondriacus

INTRODUCTION

Amaranthus is commonly called the cockscomb. The genus *Amaranthus* (Family: Amaranthaceae) contains about 60 species of mostly weedy plants widely distributed (Bailey, 1941).

Amaranthus is usually planted as open-field annuals and it require no special treatment. The species thrive in a hot and sunny place. They are coarse annual plants, grown for coloured foliage and the showy flower-cluster related to the cockscombs.. *Amaranthus* plants are very useful as dwarf and compact varieties, which often have beautiful variegated foliage, may be grown in pots or used for bedding and for the mixed border. Tall varieties are also used as cut flowers (Bailey, 1941).

A. caudatus Linn. (Red) "Love -lies-bleeding" is a tall plant, robust and diffuse. Leaves ovate-oblong, stalked green, spikes red, long slender in a long drooping panicle and the terminal one forming a long, cord-like tail, foliage blood-red.

A. hypochondriacus Linn. "Prince's Feather" common name is "Green thumb" which commonly has a tall glabrous leaves, oblong - lanceolate, acute usually purple or purple - green, spikes blunt, aggregated into a thick, lumpy terminal panicle, with the heavy heads variously coloured, but mostly purple.

The number of chemical mutagens is very great and is continuously increasing. However, for practical purposes of mutation induction in cultivated plants only few are really useful. Most of these belong to the special class of alkylating agents as ethyl methanesulphonate (EMS) $CH_3SO_2OC_2H_5$, diethyl sulphate (DES) $SO_2(OC_2H_5)_2$ and sodium azide (SA) NaN_3. Both DES and EMS act directly on guanine adding an ethyl or methyl group at carbon 7. This weakens the linkage of guanine to deoxyribose and the guanine is lost from DNA leaving a gap. Depending on which of the four bases fills in the gap transitions or transversions may eventually arise. Sodium azide is an effective mutagen under certain treatment concentrations. It is possible to obtain high mutation frequencies, most of them apparent by gene mutations with negligible frequency of chromosome aberrations. Azide in acid solutions was found to be very effective in inducing chlorophyll – deficient as well as morphological mutations. (Kleinhofs, *et al.* 1974, C.F. IAEA Technical Reports Series, 1977)

The aim of this work was to study the effect of some concentrations of the mutagenic reagents; diethyl sulphate and sodium azide on the vegetative growth and flowering of the two *Amaranthus* species.

MATERIALS AND METHODS

Amaranthus caudatus and *Amaranthus hypochondriacus* were used in this study. The seeds were obtained from "Kieft seeds"Holland. Two kinds of chemical mutagens were used in the current study i.e. Sodium Azide (SA) and Diethyl Sulphate (DES), both were obtained from Merck Co. Germany. The layout of the experiment for the M1 – generation was a spilt – spilt plot design, with three replicates (Snedecor and Cochran, 1967). Every replicate contained 12 treatments for each species (two kinds of chemical mutagens and six concentrations). The main plot represented the species, the two chemical mutagens were the sub – plot and the sub – sub plot represented the concentrations. Fifty seeds were used for each treatment in every replicate, the total number of seeds used in the experiment was 3600 divided into 24 parts (12 parts x 150 seeds for each species) and each treatment was put in a bag. Six bags from each species were soaked for one hour in distilled water at 24± 1°C (laboratory temperature) before being treated with the different chemical concentrations (0, 1000, 2000, 3000, 4000 and 5000 ppm. of each SA and DES for 5 hours, then they were washed by distilled water on April 3, 2001 and April 1, 2002 in the first and second seasons respectively.

Chemically treated and non – treated seeds were sown on April 3, 2001 in the first season and on April 1, 2002 in the second one. The seeds of each treatment were divided into three equal parts. Every part was sown in a thirty centimeters diameter clay pot filled with a mixture of equal parts of sand and clay (one pot for every replicate).The pots were placed in partial shade according to the experimental layout of the split – split plot design. On May 2, 2001 and 2002 in the first and second seasons respectively, the seedlings were individually transplanted to 15 cm. pots using clay soil as they reached a height of about 4 cm. in *A. hypochondriacus* and 8cm. in *A. caudatus*. The pots were arranged according to the spilt- spilt plot design in three replicates. The M1-field experiments were terminated on July 27, 2001 and August 15, 2002 in the first and second seasons respectively. Statistical analyses were carried out according to the methods described by Snedecor and Cochran (1967).

The following parameters were recorded in both M1– generations of the two successive experimental seasons; seed germination%, plant height (cm), mean number of main branches, average stem diameter (cm), average number of leaves and leaf area (cm^2) / plant, anthocyanin content (after Tibor and Francis, 1968), total chlorophyll content (after Yadava, 1986), fresh and dry weights (g/plant), flowering date (days from seed sowing), number of inflorescences per plant, inflorescence length (cm) and inflorescence diameter (cm).

M2 – Generation

Twenty percent of the survived M1-plants at each treatment were selected and selfed (Moh and Smith, 1951and Sinhamaha - patra and Rakshit, 1990). All visible changed off – types and abnormal M1– plants were not selected. Selfing was carried out in all changed plants to investigate the genetic basis of the changes occurred in the different characteristics. Bulked seeds of all selected and selfed M1-plants from each mutagenic treatment were collected.

On April 7, 2002 and April 5, 2003 respectively, seeds obtained from both M1-generations of the first and second seasons were sown. A sample of 150 selfed seeds from each treatment was sown in 3 wooden trays (50 seeds / tray) containing a soil mixture of 1 sand : 1 clay (by volume). The trays were placed in partial shade according to the experimental layout of spilt – spilt plots with 3 replicates and watered daily. The M2 – plants were individually transplanted to 15cm diameter clay pots using clay soil. The pots were arranged according to the experimental design mentioned before. The M2 – field experiments were terminated on August 3, 2002 and August 29, 2003 in the first and second seasons respectively.

Data were collected in both M2- generations of the two successive experimental seasons. All characters of M2- generation were measured in the same manner mentioned in the M1- generation.

RESULTS AND DISCUSSION

Effect of sodium azide and diethyl sulphate on seed germination

In the M1–generations, in both mutagens, for *A. caudatus*, the control treatment had the lowest means for seed germination percentage, while the highest means were detected at the concentrations of 5000 (64%) and 1000 ppm. SA (58%) and 1000 (36%) and 2000 ppm. DES (42%) in the first and second seasons, respectively. As for *A. hypochondriacus*, the control treatment had the lowest means for seed germination percentage, while the highest means for seed germination percentage were detected at the concentrations of 1000 (49%), 1000ppm. SA (53%) and 2000ppm DES (33, 36%) in the first and second seasons, respectively.

In the M2-generation, for *A. caudatus* the lowest seed germination percentage was also recorded at the control treatment, while the highest values were obtained at the concentrations of 5000 (58%), 1000 ppm. SA (67%) in the first and second

seasons, respectively and 1000 ppm. DES (66%) in the second season. As for *A. hypochondriacus*, the control treatment gave the lowest means, while the highest means were obtained at 1000 ppm. SA (45 and 49%) and 2000 (36%) and 4000 ppm. DES (34%) in the first and second seasons, respectively (Table 1). The changes in the results of germination percentage of the M1 and M2- generations from season to another may be due to the environmental effects, seed moisture content as well as the chemical concentrations rate (Abd El-Maksoud and El-Mahrouk, 1992).

These findings are similar to those of many investigators who indicated that there were some stimulatory effects during the germination of seeds as a result of low concentrations of mutagenic chemicals. (Hussein *et al.* 1974 on *Salvia splendens*; Wang *et al.*, 1997 on sunflowers and El-Nashar, 1998 on African marigold).

The stimulatory effect of the low and sometimes intermediate concentrations of the used chemicals on the seed germination may be due to a physiological influence. The first phase of germination is the swelling of cells by hydrates followed by enzymatic activation and metabolism.

The material and energy necessary for this initial growth are already available in the seed, and so the young embryo do not need to form new substances, but only to activate those already stored in the cotyledon. The role of the chemicals may be to increase the enzymatic activation and awake meristemic cell division in seed (Al-Halawany, 1992). The reduction of the percentage of germinated seeds as a result of high concentrations of chemicals are related to the damage of embryo which might arise from ionizing chemicals. Also this reduction may be due to the effect of high concentrations and high temperature which inhibit the synthesis of enzymes. This damage or inhibition result in a decline in the germination rate. In both seasons, there was sometimes a significant difference between the two cultivars in the percentage of germinated seeds. This difference may be due to the genetic factors, such as sensitivity as mentioned by Abd El-Maksoud (1980)

Effect of sodium azide and diethyl sulphate on the vegetative growth.

Effect on plant height

Data presented in (Table 1) for M1-generation, show that the control treatment of *A. caudatus* had the least mean of plant height, while the tallest plants were detected at the concentration of 2000 ppm. SA (53.57 cm and 74.93 cm) and 3000 (52.76 cm.) and 4000 ppm.DES (73.37 cm.) in the first and second seasons, respectively. Data recorded for *A. hypochondriacus* were not clear (Table 1), both mutagens were effective in suppressing the plant height as compared with the control except the dose of 2000 ppm. SA (7.53 and 14.13cm.), as well as the dose of 1000 ppm. DES (9.12 and 24.23 cm) in the first and second seasons, respectively, where the plants were a little bit taller than the control.

The shortest plants were detected at the concentrations of 3000 ppm. SA (5.53cm) and 5000 ppm. DES (6.91 cm).

In the M2- generation of the first season, the tallest *A. caudatus* plants were obtained at the dose of 2000 ppm. SA (58.73 and 70.80 cm.) and 5000 (67.17 cm.) and 4000 ppm. DES (71.33 cm) in the first and second seasons, respectively, while the shortest plants were obtained at 4000 ppm. SA (42.62 cm.) and 2000 ppm. DES (47.80 cm.). As for *A. hypochondriacus*, the control treatment had the shortest plants, while the tallest plants were found at 3000 ppm. SA (33.57 and 17.13 cm) and 5000 (35.90 cm.) and 4000 ppm. DES (15.23cm.) in the first and second seasons, respectively. It was found in both seasons that *A. caudatus* had taller plants than *A. hypochondriacus*. In the M1- generation, a comparison between the different means of concentrations indicated that the maximum average plant height was produced by 2000 ppm., while the minimum plant height was detected in the control.

These results supported the findings reported by Hussein *et al.* (1974) and may be due to the stimulatory effect of the low chemical mutagens rates on the plant length which could be related to the physiological activation of plant metabolism as a result of chimecal mutagens application (El-Torky, 1992). The effect of the high rate might be attributed to the physiological damage caused by chemical mutagens, and its hydrolysis products. The significant differences between the species might be due to the differences of the species in their sensitivity to chemical types and dose or to climatic and soil conditions (Al- Halawany, 1992).

These results seemed to agree also with those reported by Behera and Patnaik (1979) on *Amaranthus tricolour*; Mahna *et al.* (1991a, b and c) on *Vigna mungo*, Bohmova and Repiska (1994) on barley; El- Nashar (1998) on *Tagetes erecta* c.v. Petite Yellow, and El-Tony (1999) on *Tagetes erecta.*

Effect on the number of branches per plant

As for the M1– generations of *A. caudatus* the greatest number of branches per plant was observed at 3000 (6.09 and 6.00) and 5000 (7.89) and 4000 ppm .DES (10.67) in the first and second seasons, respectively. In the case of *A. hypochondriacus*, the greatest numbers were observed at 2000 (3.03) , 4000ppm. SA (3.09) and 4000 (2.87), 100ppm. DES (6.33) in the first and second seasons, respectively (Table 2).

Table 1: Mean values of seed germination percentage (%) and plant height (cm) of *Amaranthus caudatus* and *A. hypochondriacus* as affected by the different applications of sodium azide (SA) and diethyl sulphate (DES) for -M1 and M2 -generations in the first (2001/2002) and second (2002/2003) seasons.

Species	Mutagens	Mutagen concentrations	Seed Germination Percentage (%)				Plant Height (cm)			
			M1 Gen. 2m,001	M2 Gen. 2002	M1 Gen. 2002	M2 Gen. 2003	M1 Gen. 2001	M2 Gen. 2002	M1 Gen. 2002	M2 Gen. 2003
A. caudatus	S.A	control	21	20	26	60	35.78	54.4	62.83	55.1
		1000 ppm	54	47	58	67	51.4	56.37	61.97	57.2
		2000 ppm	44	42	50	53	53.57	58.73	74.93	70.8
		3000 ppm	35	38	40	52	46.39	50.8	71.97	63.47
		4000 ppm	50	49	55	66	42.81	42.63	71.47	61.4
		5000 ppm	64	58	56	65	38.22	56.5	56.77	61.87
	Mean of S.A		44.67	42.33	54.17	60.5	44.69	53.24	66.66	61.64
	D.E.S	control	19	21	22	53	32.93	56.13	55.07	52.73
		1000 ppm	36	29	41	66	43.62	64.07	66.9	65.6
		2000 ppm	31	27	?	53	43.37	47.8	68.77	61.6
		3000 ppm	29	27	28	45	52.76	64.17	69.73	67.63
		4000 ppm	20	18	24	41	44.98	65.37	73.37	71.33
		5000 ppm	26	25	31	42	34.72	67.17	60.57	55.97
	Mean of D.E.S		26.83	24.5	31.33	50	42.05	60.95	65.73	62.48
Mean of A. caudatus			35.75	33.42	42.75	55.25	43.37	57.09	66.19	62.06
A. hypochondriacus	S.A	control	23	20	26	28	7.14	22.73	12.17	11.4
		1000 ppm	49	45	53	49	5.9	27.4	11.1	11.03
		2000 ppm	34	29	40	45	7.53	25.2	14.13	10.83
		3000 ppm	42	40	40	47	5.53	33.57	11.3	17.13
		4000 ppm	33	28	29	38	6.64	30.2	12.6	10.4
		5000 ppm	43	41	42	35	6.24	28.03	11.13	10.37
	Mean of S.A		37.33	33.83	38.33	40.33	6.5	27.86	12.07	11.86
	D.E.S	control	18	19	23	23	7.24	24.13	11.7	12.06
		1000 ppm	25	23	30	24	9.12	25.3	24.23	10.5
		2000 ppm	33	36	36	26	7.45	34.33	20.13	11.87
		3000 ppm	26	24	27	28	6.92	28.07	12.23	9.73
		4000 ppm	32	35	29	34	8.94	35.1	20.13	15.23
		5000 ppm	27	30	30	22	6.91	35.9	13.13	12.53
	Mean of D.E.S		26.83	27.83	29.17	26.17	7.76	30.47	16.93	11.98
Mean of A. hypochondriacus			32.08	30.83	33.75	33.25	7.13	29.16	14.53	11.92
L.S.D 0.05 for Sp.			N.S	N.S	N.S	4.28	4.11	5.06	5.38	5.22
Mean of Mutagens		S.A	41	38.08	46.25	50.42	25.59	40.55	39.36	36.75
		D.E.S	26.83	26.17	30.25	38.09	24.91	45.71	41.33	37.23
L.S.D 0.05 for Mut.			3.47	3.84	3.73	3.09	N.S	N.S	N.S	N.S
Mean of concentrations		control	20.25	20	24.25	41	20.78	39.6	35.44	32.81
		1000 ppm	41	36	45.5	51	27.51	43.28	41.05	36.08
		2000 ppm	35.5	33.5	42	44.25	27.98	41.52	44.49	38.78
		3000 ppm	33	32.25	33.75	43	27.89	44.15	41.31	39.49
		4000 ppm	33.75	32.5	34.25	44.75	25.84	43.33	44.39	39.59
		5000 ppm	40	38.5	39.75	41	21.52	46.9	35.4	35.18
L.S.D 0.05 for Conc.			6.29	6.48	6.91	N.S	3.51	N.S	5.07	N.S
L.S.D 0.05 for Sp × M ×Conc.			N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S

Table 2: Mean values number of branches per plant and stem diameter (cm) of *Amaranthus caudatus* and *A. hypochondriacus* as affected by the different applications of sodium azide (SA) and diethyl sulphate (DES) for-M1 and M2 -generations in the first (2001/2002) and second (2002/2003) seasons.

Species	Mutagens	Mutagen concentrations	Number of branches per plant				Stem diameter (cm)			
			M1 Gen. 2001	M2 Gen. 2002	M1 Gen. 2002	M2 Gen. 2003	M1 Gen. 2001	M2 Gen. 2002	M1 Gen. 2002	M2 Gen. 2003
A. caudatus	S.A	control	4.36	4.85	2.33	4.00	0.55	0.64	0.57	0.61
		1000 ppm	4.93	4.78	3.67	4.31	0.62	0.57	0.69	0.64
		2000 ppm	5.90	6.20	5.59	6.70	0.73	0.56	0.74	0.85
		3000 ppm	6.09	7.06	6.00	8.33	0.51	0.53	0.91	0.79
		4000 ppm	4.78	5.19	5.28	7.72	0.48	0.43	0.82	0.89
		5000 ppm	3.80	4.32	5.07	5.21	0.57	0.47	0.75	0.67
	Mean of S.A		4.98	5.40	4.66	6.05	0.58	0.53	0.75	0.74
	D.E.S	control	4.95	5.29	3.61	4.32	0.47	0.58	0.77	0.64
		1000 ppm	5.46	5.66	7.33	6.33	0.48	0.62	0.85	0.76
		2000 ppm	6.89	7.11	2.67	3.02	0.48	0.57	0.61	0.65
		3000 ppm	7.75	8.22	4.10	2.67	0.71	0.70	0.67	0.77
		4000 ppm	4.06	5.00	10.67	8.67	0.46	0.67	0.84	0.76
		5000 ppm	7.89	7.27	3.08	3.34	0.45	0.76	0.69	0.80
	Mean of D.E.S		6.17	6.43	5.24	4.73	0.51	0.65	0.74	0.73
Mean of A. caudatus			5.57	5.91	4.95	5.39	0.54	0.59	0.74	0.74
A. hypochondriacus	S.A	control	2.76	2.84	1.33	1.66	0.23	0.32	0.31	0.30
		1000 ppm	2.35	2.71	2.30	2.65	0.26	0.41	0.36	0.38
		2000 ppm	3.03	3.57	3.03	2.34	0.29	0.31	0.45	0.39
		3000 ppm	2.36	2.48	2.57	2.00	0.25	0.44	0.41	0.32
		4000 ppm	2.10	2.29	3.09	2.67	0.24	0.36	0.32	0.32
		5000 ppm	2.26	2.23	2.29	2.35	0.26	0.47	0.34	0.37
	Mean of S.A		2.48	2.69	2.44	2.28	0.26	0.39	0.37	0.35
	D.E.S	control	2.10	2.16	2.00	2.29	0.22	0.31	0.32	0.33
		1000 ppm	1.87	2.47	6.33	3.06	0.27	0.29	0.42	0.40
		2000 ppm	1.79	2.24	3.11	1.67	0.28	0.35	0.62	0.41
		3000 ppm	1.91	2.30	3.52	3.00	0.24	0.39	0.38	0.39
		4000 ppm	2.87	2.87	4.28	4.67	0.27	0.68	0.42	0.25
		5000 ppm	1.93	2.04	2.64	3.33	0.23	0.48	0.36	0.34
	Mean of D.E.S		2.08	2.34	3.65	3.00	0.25	0.41	0.42	0.37
Mean of A. hypochondriacus			2.27	2.52	3.04	2.64	0.25	0.40	0.39	0.36
L.S.D 0.05 for Sp.			0.54	1.47	1.97	N.S.	0.09	0.10	0.22	0.11
Mean of Mutagens	S.A		3.73	4.04	3.55	4.17	0.42	0.46	0.56	0.54
	D.E.S		4.12	4.39	4.45	3.87	0.38	0.53	0.58	0.55
L.S.D 0.05 for Mut.			N.S.	N.S.	3.55	4.17	N.S.	0.07	N.S	N.S.
Mean of concentrations		control	3.54	3.78	2.32	3.07	0.37	0.46	0.49	0.48
		1000 ppm	3.65	3.91	4.91	4.09	0.40	0.47	0.58	0.55
		2000 ppm	4.40	4.78	3.60	3.43	0.40	0.45	0.61	0.57
		3000 ppm	4.53	5.02	4.05	4.00	0.43	0.52	0.59	0.57
		4000 ppm	3.45	3.84	5.83	5.93	0.36	0.53	0.60	0.58
		5000 ppm	3.97	3.97	2.33	4.00	0.38	0.55	0.54	0.55
L.S.D 0.05 for Conc.			0.74	0.59	3.67	4.31	N.S.	N.S.	N.S	0.07

From the results mentioned before, it was clear that some mutagen concentrations were able to increase the number of main branches per plant. These results are in conformity with those reported by Prasad and Tripathi (1986) on barley; Vandana and Dubey (1993) on *Vicia faba*; Mahna *et al.* (1994) on *Vigna aconitifolia* and Khan *et al.* (1996) on *Vigna radiata*. On the contrary, other workers mentioned that chemical mutagens reduced the number of main branches per plant such as: Rao and Reddi (1987) on rice; Abd El-Maksoud and El-Mahrouk (1992) on *Asparagus densiflorus* and Mohideen and Irulappan (1993) on *Amaranthus*. These effects may by due to the sensitivity of the different plant species to the used concentrations of the chemical mutagens.

Effect on stem diameter

As for the M1-generation, the data presented in Table 2. show the mean values of stem diameter by using different treatments in both species. Concerning *A. caudatus* the greatest stem diameters were found at the treatments of 2000 (0.73 cm.), 3000 ppm. SA (0.91 cm.) and 3000 (0.71 cm.), 1000 ppm. DES (0.85) in the first and second seasons, respectively. As for *A. hypochondriacus*, the greatest stem diameters were found at 2000 ppm. SA (0.29 and 0.45 cm) and 2000 ppm. DES (0.28 and 0.62cm.) in the first and second seasons, respectively.

In M2- generations of *A. caudatus*, the greatest stem diameters for both mutagens were obtained at the doses of zero (0.64 cm.), 4000 ppm. SA (0.89 cm.) and 5000 ppm. DES (0.76 and 0.80 cm.) in the first and second seasons, respectively. As for *A. hypochondriacus*, the greatest stem diameters were obtained at 5000 (0.47cm.), 2000 ppm. SA (0.39 cm.) and 4000 (0.68 cm.), 2000 ppm. DES (0.41 cm.) in the first and second seasons, respectively.

The comparison between the two species, in both generations, indicated that *A. candatus* had larger average stem diameters than *A. hypochondriacus*. In the M2-generation, the comparison between the two mutagens revealed that the DES had the highest average stem diameters.

Stimulation and reduction in stem diameter could be attributed to the effect of low and high concentration of chemical mutagens on the cell numbers and cell length. Cells number and length may be altered in the stem of plants following the chemical treatment. Large stem had larger branches with an increase in cells number and / or cell size. Small stem had smaller branches with a decrease in cells number and / or cell size (Bidwell, 1974).

Effect on leaf measurements

Effect on the number of leaves per plant

In the M1- generations, in the case of *A. caudatus* the highest number of leaves per plant was obtained at 5000 (30.32), 4000 ppm. SA (46.53) and 3000 (31.21) and 4000 ppm. DES (46.00) in the first and second seasons, respectively. As for *A. hypochondriacus*, the highest numbers were obtained at 2000 (7.83 and 15.67) and 4000 (7.04), 1000 ppm. DES (14.03) in the first and second seasons, respectively (Table 3).

In the M2-generations, for *A. caudatus*, the highest numbers were obtained at 5000 (25.67), 4000 ppm. SA (37.70) and 1000 (28.07) , 4000 ppm. DES (43.13) in the first and second seasons, respectively. As for *A. hypochondriacus*, the highest numbers were obtained at 1000 (13.87) , 2000 ppm. SA (12.03) and 5000 (12.00), 1000 ppm. DES (18.67) in the first and second seasons, respectively.

The comparison between the two species data indicated that *A. caudatus* had more leaves per plant than *A. hypochondriacus*.

The reported data showed that there were no significant differences among the effects of the different mutagen concentrations during M1- and M2- generations of the first season, the number of leaves per plant did not significantly decrease, as compared with the control, which means that with increasing the concentrations, the number of leaves per plant decreased. Except for M1- generation of *A. caudatus*, the number of leaves per plant increased, as compared with the control, as a kind of positive correlation. These results are in agreement with those reported by Hussein *et al.* (1974) on *Salvia splendens;* Neagu (1974) on sunflower; Conger and Carabia (1977) on maize; Rao and Reddi (1987) on rice; Krivitskii *et al.* (1989) on *Amaranthus* and El-Nashar (1998) on *Tagetes erecta* c.v. Petite Yellow.

The differences between the species might be due to the differences of the species in their sensitivity to chemical types and mutagen concentrations or to climatic factors such as light, temperature or soil conditions (Al-Halawany, 1992).

Effect on leaf area

In the M1- generations, the data presented in Table 3 show the mean values of leaf area by using different treatments of both species. In both mutagens for *A. caudatus* the greatest leaf area was detected at the concentration of 2000 ppm. SA (7.02 and 14.01 cm^2) and 3000 (6.19 cm^2), 4000 ppm. DES (23.26 cm^2) in the first and second seasons, respectively.

As for *A. hypochondriacus*, the greatest leaf area was detected at the concentrations of 4000 (4.15 cm^2), 2000 ppm. SA (8.53 cm^2) and 4000 ppm. DES (4.21 cm^2), 2000 ppm. DES (9.09 cm^2) in the first and second seasons, respectively.

With respect to the M2-generations, the greatest leaf area for *A. caudatus* was detected at the concentrations of 5000 (8.63 cm^2), 3000 ppm. SA (15.00 cm^2) and 4000 (14.11 cm^2), 4000 ppm. DES (23.11cm^2) in the first and second seasons, respectively. As for *A. hypochondriacus*, the

greatest leaf area was detected at the concentrations of 3000 (5.74 cm^2), 2000 ppm. SA (7.89 cm^2) and 3000 (5.19cm^2), 2000 ppm. DES (8.83 cm^2) in the first and second seasons, respectively.

The comparison between the two mutagens, in both M1-and M2-generations indicated that *A. caudatus* had larger average leaf area. The comparison between the two mutagens, in both generations, showed that the DES had the highest average leaf area.

Table 3: Mean values of number of leaves per plant and leaf area (cm^2) of *Amaranthus caudatus* and *A. hypochondriacus* as affected by the different applications of sodium azide (SA) and diethyl sulphate (DES) for-M1 and M2 -generations in the first (2001/2002) and second (2002/2003)seasons.

Species	Mutagens	Mutagen concentrations	Number of leaves per plant				Leaf area (cm^2)			
			M1 Gen. 2001	M2 Gen. 2002	M1 Gen. 2002	M2 Gen. 2003	M1 Gen. 2001	M2 Gen. 2002	M1 Gen. 2002	M2 Gen. 2003
A. caudatus	S.A	control	15.91	20.67	14.23	19.77	6.42	5.79	13.84	11.01
		1000 ppm	19.87	12.03	20.13	25.93	6.59	5.09	11.99	7.66
		2000 ppm	19.91	14.00	24.23	20.97	7.02	8.04	14.01	14.66
		3000 ppm	19.73	14.70	25.80	29.67	6.21	5.39	10.62	15.00
		4000 ppm	19.93	17.80	46.53	37.70	4.68	4.75	10.89	7.91
		5000 ppm	30.32	25.67	30.80	34.30	5.52	8.63	12.56	8.26
	Mean of S.A		20.94	17.48	26.96	28.07	6.07	6.28	12.32	10.75
	D.E.S	control	19.42	23.30	27.37	27.50	4.89	4.36	15.10	13.36
		1000 ppm	23.86	28.07	40.87	35.97	3.96	5.51	13.90	12.23
		2000 ppm	19.09	19.43	21.33	17.67	4.25	5.92	18.68	18.44
		3000 ppm	31.21	19.87	22.73	22.53	6.19	7.35	18.80	19.57
		4000 ppm	22.51	21.73	46.00	43.13	5.96	14.11	23.26	23.11
		5000 ppm	21.48	19.70	18.00	24.43	3.46	9.37	17.82	16.73
	Mean of D.E.S		22.93	22. 02	29.38	28.54	4.78	7.77	17.93	17.57
Mean of A. caudatus			21.94	19.75	28.17	28.31	5.43	7.02	15.12	14.16
A. hypochondriacus	S.A	control	7.32	11.73	7.57	8.27	3.40	3.86	5.43	4.93
		1000 ppm	6.62	13.87	9.63	12.00	4.06	3.25	6.91	5.92
		2000 ppm	7.83	9.10	15.67	12.03	3.60	3.95	8.53	7.89
		3000 ppm	6.41	13.13	11.07	9.23	2.69	5.74	6.74	7.10
		4000 ppm	6.30	11.47	9.03	8.70	4.15	3.69	4.72	5.34
		5000 ppm	5.70	10.67	10.93	9.80	2.83	3.51	6.74	6.15
	Mean of S.A		6.69	11.66	10.65	10.01	3.46	4.00	6.51	6.22
	D.E.S	control	6.10	11.23	10.00	8.73	3.28	4.43	5.50	5.68
		1000 ppm	6.50	10.23	14.03	18.67	3.56	4.61	8.03	7.13
		2000 ppm	5.28	11.17	12.57	9.60	4.13	4.23	9.09	8.83
		3000 ppm	4.56	8.77	10.06	7.43	3.30	5.19	5.70	4.60
		4000 ppm	7.04	11.27	12.73	9.97	4.21	4.22	7.64	4.28
		5000 ppm	4.64	12.00	11.83	8.93	3.17	3.83	7.20	4.68
	Mean of D.E.S		5.69	10.78	11.87	10.56	3.61	4.42	7.19	5.86
Mean of A. hypochondriacus			6.19	11.22	11.26	10.28	3.53	4.21	6.85	6.04
L.S.D 0.05 for Sp.			3.77	5.30	14.85	17.69	1.85	1.68	5.43	1.33
Mean of Mutagens		S.A	13.82	14.57	18.80	*36.75*	4.77	5.14	9.42	8.49
		D.E.S	14.31	16.39	20.63	37.23	4.19	6.09	12.56	11.72
L.S.D 0.05 for Mut.			N.S	N.S	N.S.	N.S.	N.S.	N.S.	1.08	1.98
Mean of concentrations		control	12.19	16.73	14.75	16.07	4.50	4.61	9.97	8.74
		1000 ppm	14.21	16.05	21.17	23.14	4.54	4.61	10.21	8.24
		2000 ppm	13.03	13.43	18.45	15.07	4.75	5.53	12.58	12.45
		3000 ppm	15.48	14.12	17.46	17.24	4.59	5.92	10.47	11.57
		4000 ppm	13.94	15.57	28.58	24.88	4.75	6.69	11.63	10.66
		5000 ppm	15.54	17.01	17.89	19.37	3.74	6.33	11.08	8.95
L.S.D 0.05 for Conc.			N.S	N.S	5.26	6.45	N.S.	N.S.	N.S.	2.33

Similar results were reported by Hussein *et al.* (1974) on *Salvia splendens*, Neagu (1974) on sunflower; Desai and Smith (1974) on *Sorghum bicolor*; Sinha (1990) on *Lindenbergia indica*; Al-Halawany (1992) on *Catharanthus roseus*; Abd El-Maksoud and El-Mahrouk (1993) on *Cardiospermum halicacabum* and El-Nashar (1998) on *Tagetes erecta.*

Leaf area is a quantitative character which can be affected by SA and DES treatments. In this respect, the absence of the induced variability may be attributed to environmental factors such as light, temperature, nutrition etc. (Reda, 1978 and Arntz *et. al.* 2000).

Effect on leaf pigments

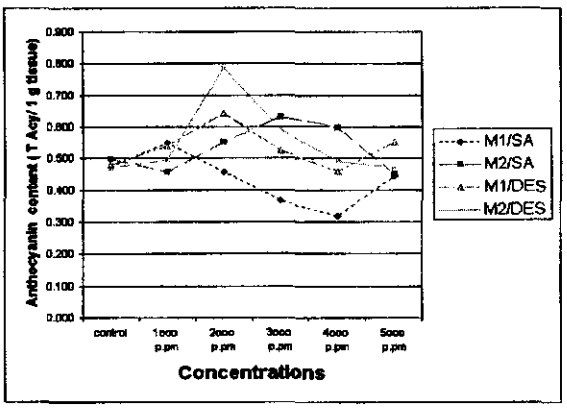
Anthocyanin content

In the M1- generation, the data presented in Figure 1 shows, for *A. caudatus*, that the highest averages were noticed at 1000 (0.550 T Acy/1g tissue), 3000 ppm. SA (0.607 T Acy/1 g tissue) and 2000 (0.643 T Acy /1g tissue), 4000 ppm. DES (0.591 T Acy /1g tissue) in the first and second seasons, respectively.

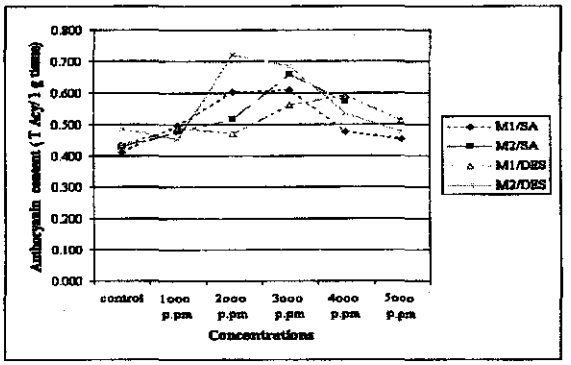
In the M2–generations, the highest averages were obtained at 3000 ppm. SA (0.630 and 0.657T Acy/1g tissue) and 2000 ppm. DES (0.787 and 0.719T Acy/1g tissue) in the first and second seasons, respectively.

These results are in agreement with those of Behera and Patnaik (1979) on *A. tricolor* and *A. hypochondriacus* and Odeigah *et al.* (1999) on cowpea.

The reduction in anthocyanin pigment as a result of treating with high concentrations of chemicals are related to the damage of embryo which might arise from ionizing chemicals. Also this reduction may be due to the effect of the high concentrations which inhibit the synthesis of enzymes. This damage or inhibition results in a decline in the anthocyanin pigment (Odeigah *et al.*, 1999).



First season

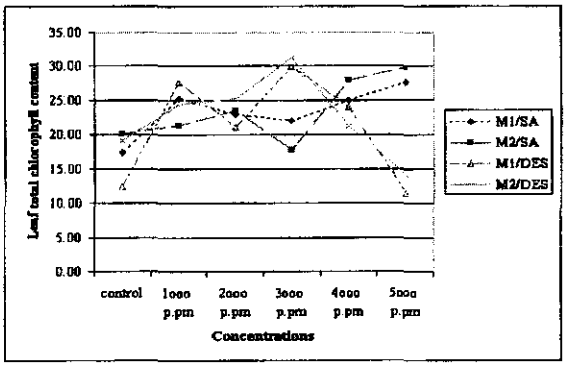


Second season

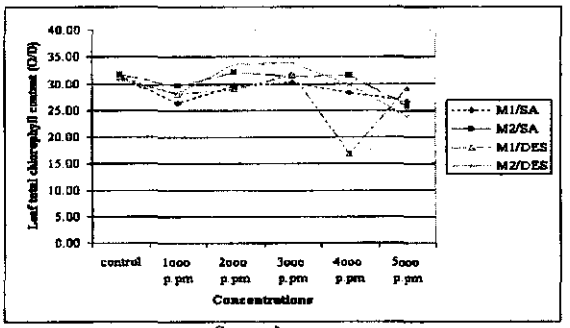
Fig. 1: Mean values for anthocyanin content (T Acy/1g tissue) of *Amaranthus caudatus* as affected by the different applications of sodium azide (SA) and diethyl sulphate (DES) for M1-and M2-generations of the first and second seasons.

Chlorophyll content

In the M1–generation, (Figure 2), it was evident in *A. hypochondriacus* that the highest averages were noticed at 5000 (27.63 O/D) and zero ppm. SA (31.33 O/D) and 3000 ppm. DES (29.90 and 31.80 O/D) in the first and second seasons, respectively.



First season



Second season

Fig. 2: Mean values for leaf total chlorophyll content (O/D) of *Amaranthus hypochondriacus* as affect ed by the different applicationsof sodium azide (SA) and diethyl sulphate (DES) for M1-and M2-generations of the first and second seasons.

In the M2- generation, the highest averages were obtained at 5000 (29.77 O/D), 2000 ppm. SA (32.20 O/D) and 3000 ppm. DES (31.20 and 33.86 O/D) in the first and second seasons, respectively.

Similar findings were reported by Al-Halawany, (1992) on *Catharanthus roseus* and Rybinski *et al.* (1994) on barley. Many workers reported that chlorophyll content was stimulated in the first season, as a result of low and intermediate mutagen concentrations, for example, Badami and Bhalla (1994) on *Cyamopsis tetragonolaba* and Rybinski (2003) on *Lathyrus sativus.*

Effect on fresh weight of plant

In the M1 (Table 4), it was evident, for both mutagens, in the case of *A. caudatus* that the heaviest fresh weights were obtained at the concentrations of 2000 (20.46 g), 3000 ppm. SA (61.00g) and 3000 (19.91g), 1000 ppm. DES (56.83g) in the first and second seasons, respectively. As for *A. hypochondriacus*, the greatest values were detected at 1000 (8.00 g), 3000 ppm. SA (8.98) and 2000 (6.44g), 1000 ppm. DES (17.23g) in the first and second seasons, respectively.

In the M2- generations, for *A. caudatus*, the greatest fresh weights were obtained at zero (13.89 g), 2000 ppm. SA (52.76g) and 1000 (22.14g), 4000 ppm. DES (46.74 g) in the first and second seasons, respectively. As for *A. hypochondriacus*, the greatest weights were obtained at 3000 ppm. SA (18.99 and 5.08 g) and 2000 (14.32 g), 1000 ppm. DES (7.09g) in the first and second seasons, respectively.

The comparison between the two species, in both generations indicated that *A. caudatus* had heavier fresh weights than *A. hypochondriacus*. The variability between the two generations can be attributed to the environmental factors prevailed during the growth period.

Effect on dry weight of plant

As for the M1- generation, for *A. caudatus*, the greatest dry weights of plant were recorded at the concentrations of 2000 ppm. SA (5.93 and14.49 g) and 3000 (6.77 g) ,4000 ppm. DES (15.22 g) in the first and second seasons, respectively. In the case of *A. hypochondriacus*, the greatest dry weights of plant were obtained at the concentrations of 1000 (3.17 g), 3000 ppm. SA (2.41 g) and zero (2.18 g) ,1000 ppm. DES (5.58 g) in the first and second seasons, respectively (Table 4).

In the M2- generations for *A. caudatus*, the greatest dry weights of plant were obtained at zero (5.08 g), 2000 ppm. SA (15.42 g) and 1000 (7.05 g), 4000 ppm. DES (12.45 g)) in the first and second seasons, respectively. As for *A. hypochondriacus*, the greatest dry weights of plants were detected at the concentrations of 3000 (5.72 g), 1000 ppm. SA (1.34g) and 4000 (5.07g), 2000 ppm. DES (1.90g) in the first and second seasons, respectively.

The comparison between the two species in the M1–generations revealed that *A. caudatus* had larger average dry weight than *A. hypochondriacus*. The comparison between two mutagens, in both generations, showed that the DES had the highest average dry weight.

The reported data showed that there were no significant differences among the effects of the different mutagen concentrations during M2-generation of the first season, and M1- generation of the second season. El-Nashar (1998) found similar results on *Tagetes erecta.* The variability between the two seasons can be attributed to the environmental factors prevailed during the growth period of both generations.

Effect of sodium azide and diethyl sulphate on the flowering characteristics

Effect on the flowering date

Regarding the M1- generation, it was found that in the case of *A. caudatus*, the earliest flowering dates were detected at the concentrations of zero ppm. SA (37.67 and 53.33 days) and 1000 (37.67 days), 4000 ppm. DES (60.66 days , while the latest flowering dates were detected at 2000 (52.00 days), 4000 ppm. SA (60.66 days) and 3000 (59.06 days)) and 5000 ppm. DES (70.33 days) in the first and second seasons, respectively. As for *A. hypochondriacus*, the earliest flowering dates were obtained at 2000 ppm. SA (36.30 and 33.33 days) and 1000 ppm. DES (37.67 and 34.60 days), while the 5000 ppm. SA (45.33 and 49.66 days) had the latest flowering dates as well as the 5000 (52.67 days), 3000 ppm. DES (51.33 days) in the first and second seasons, respectively (Table 5).

In the M2-generation of *A. caudatus*, the earliest flowering dates were detected at zero ppm. SA (40.00 and 53.67 days) and zero ppm. DES (40.33 and 51.00 days), while the latest flowering dates were detected at the concentrations of 2000 ppm. SA (53.33 and 59.30 days) and 5000 ppm. DES (58.00 and 69.33 days) in the first and second seasons, respectively. As for *A. hypochondriacus*, the earliest flowering dates were obtained at 1000 (34.33 days), zero ppm. SA (35.33 days) and zero, 1000 ppm. DES (37.67 and 34.33 days), while the latest flowering dates were detected at the concentrations of 5000 ppm. SA (45.00 and 47.33 days) and 5000 (49.00 days), 3000 ppm. DES (47.30 days) in the first and second seasons, respectively In both generations, the comparison between the means of the different concentrations, showed that the control plants flowered earlier than all concentrations in both generations. The plants at the concentration of 5000 ppm. were the latest in flowering. It is known that low and intermediate concentrations of these chemicals, generally, stimulate cell growth, increase the rate of growth and produce earlier flowering in specific cases as reported by Warfield (1973

Table 4: Mean values of fresh and dry weights of plant (g.) of *Amaranthus caudatus* and *A. hypochondriacus* as affected bythe different applications of sodium azide (SA) and diethy sulphate (DES) in- M1 and M2-generations of the first and second seasons.

Species	Mutagens	Mutagen concentrations	Fresh weight of plant (g)				Dry weight of plant (g)			
			M1 Gen. 2001	M2 Gen. 2002	M1 Gen. 2002	M2 Gen. 2003	M1 Gen. 2001	M2 Gen. 2002	M1 Gen. 2002	M2 Gen. 2003
A. caudatus	S.A	control	10.77	13.89	33.60	43.21	4.07	5.08	7.24	8.24
		1000 ppm	13.01	10.50	36.18	34.52	3.62	3.83	7.64	6.63
		2000 ppm	20.46	11.71	48.69	52.76	5.93	4.26	14.49	15.42
		3000 ppm	10.50	10.87	61.00	45.77	3.18	3.22	12.43	9.11
		4000 ppm	10.75	6.19	47.70	47.46	3.07	1.58	10.04	9.00
		5000 ppm	10.12	7.02	48.56	35.05	2.73	2.65	8.95	7.27
	Mean of S.A		12.6	10.03	45.62	43.13	3.77	3.44	10.13	9.28
	D.E.S	control	9.17	16.28	42.46	37.29	3.66	5.88	9.58	8.88
		1000 ppm	8.77	22.14	56.83	45.85	2.91	7.05	11.32	10.35
		2000 ppm	10.71	13.02	37.20	35.50	4.55	5.84	7.53	6.80
		3000 ppm	19.91	21.15	34.82	39.24	6.77	6.32	7.65	9.52
		4000 ppm	6.99	19.36	56.75	46.74	2.13	6.16	15.22	12.45
		5000 ppm	10.32	15.98	28.01	29.61	2.82	5.84	6.83	6.22
	Mean of D.E.S		10.98	17.99	42.68	39.04	3.81	6.18	9.69	9.04
Mean of A. caudatus			11.79	14.01	44.15	41.08	3.79	4.81	9.91	9.16
A. hypochondriacus	S.A	control	4.80	8.39	3.78	4.51	1.35	2.87	0.90	1.20
		1000 ppm	8.00	12.24	3.63	3.31	3.17	4.35	1.11	1.34
		2000 ppm	5.71	9.11	6.25	4.14	2.46	2.91	1.76	1.22
		3000 ppm	7.15	18.99	8.98	5.08	2.41	5.72	2.41	1.06
		4000 ppm	6.17	15.03	3.98	3.47	1.84	3.81	1.03	0.93
		5000 ppm	3.48	13.59	5.82	5.02	1.01	5.57	2.02	0.96
	Mean of S.A		5.88	12.89	5.41	4.26	2.04	4.21	1.53	1.12
	D.E.S	control	5.95	9.07	4.06	3.92	2.18	3.28	1.38	1.52
		1000 ppm	5.38	10.90	17.23	7.09	1.92	3.50	5.58	1.26
		2000 ppm	6.44	14.32	10.64	5.79	2.00	4.62	2.78	1.90
		3000 ppm	4.33	8.64	5.13	3.88	1.58	2.81	1.53	0.98
		4000 ppm	5.73	14.24	8.77	5.60	2.13	5.07	2.56	1.54
		5000 ppm	4.57	11.83	7.71	5.23	1.69	3.93	2.11	1.19
	Mean of D.E.S		5.40	11.50	8.92	5.25	1.92	3.87	2.66	1.40
Mean of A. hypochondriacus			5.64	12.20	7.16	4.75	1.94	4.04	2.10	1.26
L.S.D 0.05 for Sp.			1.22	N.S.	10.27	4.92	1.28	N.S.	2.77	3.78
Mean of Mutagens		S.A	9.24	11.46	25.51	23.69	2.90	3.82	5.84	5.20
		D.E.S	8.19	14.74	25.8	22.15	2.86	5.02	6.17	5.22
L.S.D 0.05 for Mut.			N.S.	N.S.	N.S	N.S	N.S	N.S	N.S.	N.S.
Mean of concentrations		control	7.67	11.91	20.98	22.24	2.81	4.28	4.78	4.96
		1000 ppm	8.79	13.94	27.97	22.69	2.90	4.68	6.41	4.89
		2000 ppm	10.83	12.04	25.69	24.54	3.73	4.41	6.64	6.34
		3000 ppm	10.47	14.91	27.48	23.49	3.49	4.52	6.01	5.17
		4000 ppm	7.41	13.71	29.30	25.82	2.29	4.15	7.21	5.98
		5000 ppm	7.12	12.11	22.52	18.73	2.06	4.50	4.98	3.91
L.S.D 0.05 for Conc.			2.61	N.S.	N.S	N.S	0.75	N.S.	N.S.	N.S.

Table 5: Mean values of flowering date (days) and number of inflorescences per plant of *Amaranthus caudatus* and *A. hypochondriacu* as affectedby the different applications of sodium azide (SA) and diethyl sulphate (DES) in M1 and M2 -generations of the first and second seasons.

Species	Mutagens	Mutagen concentrations	Flowering date (days)				Number of inflorescences per plant			
			M1 Gen. 2001	M2 Gen. 2002	M1 Gen. 2002	M2 Gen. 2003	M1 Gen. 2001	M2 Gen. 2002	M1 Gen. 2002	M2 Gen. 2003
A. caudatus	S.A	control	37.67	40.00	53.33	53.67	3.00	3.67	2.87	3.33
		1000 ppm	45.67	47.00	56.27	55.06	5.67	5.01	7.68	4.67
		2000 ppm	52.00	53.33	55.61	59.30	4.00	5.07	5.33	3.67
		3000 ppm	48.00	47.42	57.71	56.33	7.67	7.69	7.36	8.67
		4000 ppm	39.02	45.01	60.66	58.57	5.69	6.31	5.66	10.30
		5000 ppm	39.98	51.03	57.59	57.11	4.17	5.12	4.11	4.26
	Mean of S.A		43.72	47.28	56.86	56.67	5.03	5.48	5.50	5.82
	D.E.S	control	39.67	40.33	53.33	51.00	3.30	3.23	4.06	5.10
		1000 ppm	37.67	45.34	58.26	55.61	7.47	6.67	6.68	5.66
		2000 ppm	46.31	47.00	64.31	60.32	5.87	7.03	2.63	4.00
		3000 ppm	59.06	53.32	66.58	61.47	4.84	5.08	7.03	6.30
		4000 ppm	52.02	51.67	62.30	61.89	6.67	7.30	9.61	10.66
		5000 ppm	54.67	58.00	70.33	69.33	7.33	7.49	3.67	4.31
	Mean of D.E.S		48.67	49.28	62.52	59.94	5.91	6.13	5.61	6.01
Mean of A. caudatus			45.98	48.28	59.69	58.35	5.47	5.81	5.56	5.91
A. hypochondriacus	S.A	control	36.67	35.30	35.61	35.33	2.47	4.11	2.00	2.07
		1000 ppm	39.32	34.33	37.12	37.21	3.33	3.67	2.32	2.33
		2000 ppm	36.30	36.68	33.33	35.38	3.00	3.23	3.33	3.89
		3000 ppm	41.28	39.65	38.30	38.04	2.83	4.04	5.36	2.66
		4000 ppm	44.62	41.67	47.29	44.62	4.33	5.38	3.64	2.30
		5000 ppm	45.33	45.00	49.66	47.33	2.67	3.67	3.21	1.77
	Mean of S.A		40.59	38.78	40.22	39.65	3.11	4.02	3.31	2.50
	D.E.S	control	38.33	37.67	35.00	36.42	2.67	3.00	2.36	2.06
		1000 ppm	37.67	38.66	34.60	34.33	5.00	5.33	6.13	2.36
		2000 ppm	47.00	43.01	42.66	40.31	3.67	4.67	4.21	1.98
		3000 ppm	45.09	43.61	51.33	47.30	6.00	5.67	5.38	6.07
		4000 ppm	49.26	47.05	44.30	44.64	6.33	6.00	5.24	3.10
		5000 ppm	52.67	49.00	46.59	45.59	3.67	3.66	3.36	3.33
	Mean of D.E.S		45.00	43.17	42.41	41.43	4.56	4.72	4.45	3.15
Mean of A. hypochondriacus			42.80	40.97	41.32	40.54	3.83	4.37	3.88	2.83
L.S.D 0.05 for Sp.			N.S	5.71	2.62	2.70	N.S.	N.S.	N.S.	2.04
Mean of Mutagens	S.A		42.16	43.03	48.54	48.16	4.07	4.75	4.41	4.16
	D.E.S		46.62	46.22	52.47	50.69	5.24	5.43	5.03	4.58
L.S.D 0.05 for Mut.			1.84	2.35	2.01	1.62	1.1	N.S.	N.S.	N.S.
		control	38.09	38.33	44.32	44.11	2.86	3.50	2.82	3.14
		1000 ppm	40.08	41.33	46.55	45.55	5.37	5.17	5.70	3.76
		2000 ppm	45.40	45.00	48.98	48.83	4.14	5.00	3.88	3.39
		3000 ppm	48.36	46.00	53.48	50.54	5.33	5.62	6.28	5.93
		4000 ppm	46.23	46.33	53.64	52.43	5.76	6.25	6.04	6.59
		5000 ppm	48.16	50.75	56.04	54.84	4.46	4.99	3.59	3.42
L.S.D 0.05 for Conc.			3.45	3.12	2.45	1.70	1.69	1.42	2.66	2.36

These results are in agreement with those reported by Hussein *et al.* (1974) on *Salvia splendens*, Neagu (1974) on sunflower; Mikaelyan (1980) on *Solanum melongena*; Prasad and Tripathi (1986) on barley; Rao and Reddi (1987) on rice; Mahna *et al.* (1991a) on *Vinga aconitifola*; Vandana and Dubey (1993) on *Vicia faba*; Khan *et al.* (1996) on *Vigna radiata* and Patil *et al.* (2002) on soybean.

Effect on the number of inflorescences per plant

Data presented in Table 5 show the mean values of the number of inflorescences per plant of the M1- generation for *A. caudatus* . The greatest values were detected at the concentrations of 3000 (7.67), 1000 ppm. SA (7.68) and 1000 (7.47), 4000 ppm. DES (9.61) in the first and second seasons, respectively. As for *A. hypochondriacus*, the greatest values were obtained at 4000 (4.33), 3000 ppm. SA (5.36) and 4000 (6.33), 1000 ppm. DES (6.13) in the first and second seasons, respectively.

In the M2- generations, for *A. caudatus* the control treatment had the lowest mean number of inflorescences per plant, while the greatest values were obtained at 3000 (7.69), 1000 (10.30) ppm. SA and 5000 (7.49), 4000 ppm. DES (10.66) in the first and second seasons, respectively. As for *A. hypochondriacus*, the greatest values were detected at the concentrations of 4000 (5.38), 2000 ppm. SA (3.89) and 4000 (6.00) and 3000 ppm. DES (6.07) in the first and second seasons, respectively.

The comparison between the two species in the M1–generation data revealed that *A. caudatus* had larger average number of inflorescences per plant than *A. hypochondriacus*. The comparison between the two mutagens, in both generations, data showed that DES had the highest average number of inflorescences per plant. The comparison among the different means of concentrations data indicated that the control treatment had the smallest average number of inflorescences per plant, while the largest one was observed at the concentration of 4000 ppm.

The obtained data showed that there were significant differences among the effects of the different mutagen concentrations during M1- and M2- generations in the first and second seasons. Almost the number of inflorescences per plant was significantly increased in positive correlation with concentrations, as compared to the control. Stimulation and reduction in inflorescence number could be attributed to the effect of low and high concentrations of chemical mutagens on the initiation of flowering buds (Biidwell, 1974).

These results are in agreement with those reported by Al-Saheal and Gamil (1982) on wheat; Vandana (1994) on *Vicia faba*; El-Nashar (1998) on *Tagetes erecta*; Sahu and Patra (1998) on *Phaseolus radiatus* and El-Tony (1999) on *Tagetes erecta.*

Effect on inflorescence length

Data on the average inflorescence length are shown in Table 6. In the M1, for *A. caudatus*, the shortest inflorescences were recorded at zero (15.35 cm),1000 ppm. SA (25.10 cm.) and zero ppm. DES (16.26 and 22.77 cm), while the longest ones were recorded at the concentrations of 2000 ppm. SA (28.26 and 34.17 cm) and 3000 (27.84 cm), 2000 ppm. DES (30.83 cm) in the first and second seasons, respectively. As for *A. hypochondriacus*, the shortest inflorescences were detected at the concentrations of 3000 ppm. SA (3.33 and 7.77 cm) and zero ppm. DES (4.62 and 9.20 cm), while the longest ones were obtained at zero (5.28 cm), 2000 ppm. SA (11.10 cm) and 4000 (6.22 cm), 1000 ppm. DES (15.83 cm) in the first and second seasons, respectively.

In the M2- generation of the first season, for *A. caudatus*, the shortest inflorescences were obtained at the doses of 1000 (13.67 cm), 4000 ppm. SA (22.60 cm) and 2000 (14.93 cm), 5000 ppm. DES (13.70 cm.), while the longest ones were obtained at 2000 ppm. SA (19.13 cm and 31.70) and 1000 (20.97 cm), 4000 ppm. DES (28.47) in the first and second seasons, respectively. As for *A. hypochondriacus*, the shortest inflorescences were recorded at 2000 (11.43 cm), 5000 ppm. SA(7.70) and zero (10.73 cm), 3000 ppm. DES (7.63), while the longest ones were found at 3000 ppm. SA (17.70 and 8.83 cm) and 2000 (16.33 cm) and 4000 ppm. DES (11.57 cm) in the first and second seasons, respectively.

The comparison between the two species in both generations, data indicated that *A. caudatus* had longer inflorescences than *A. hypochondriacus*. The comparison between the two mutagens, data showed that SA had the longer inflorescences than DES.

These results are in agreement with those reported by Sahu and Patra (1998) on *Phaseolus radiatus*. On the contrary, data indicated that there were no significant differences in the inflorescences length among the mutagen concentrations in M2-generation of the first season, and both generations in the second season. These results are in agreement with those reported by Hassan *et al.* (1990) on wheat who found that the SA- treatment induced a greater reduction in spike length. Stimulation and reduction in inflorescence length could be attributed to the effect of low and high concentrations of chemical mutagens on the cell number and cell length. (Bidwell, 1974).

Effect on inflorescence diameter

In the M1- generations, the mean values of inflorescence diameter revealed that the control treatment of *A. caudatus* (1.10 cm), 5000 ppm. SA (1.90 cm) and zero (1.40 cm), 3000 ppm. DES (1.46 cm), had the least mean of diameter while the greatest ones were found at the concentrations of 2000 ppm. SA (1.56 and 2.63 cm) and 2000 (1.98cm), 4000 ppm. DES (2.49cm). As for *A. hypochondriacus*, the least inflorescence diameters

were detected at the concentrations of zero ppm. SA (1.24 and 1.85 cm) and zero DES (1.83 cm) and 3000 DES (0.99 cm.), while the greatest diameters were obtained at 1000 (1.97 cm.), 2000 ppm. SA (2.77 cm) and 1000 ppm. DES (1.58 and 2.56 cm.) in the first and second seasons, respectively (Table 6).

Table 6: Mean values of inflorescence length (cm) and inflorescence diameter (cm) of *Amaranthus caudatus* and *A. hypochondriacus* a affected by the different applications of sodium azide (SA) and diethyl sulphate (DES) in M1 and M2 - generations of the first and second seasons.

Species	Mutagens	Mutagen concentrations	Inflorescence length (cm)				Inflorescence diameter (cm)			
			M1 Gen. 2001	M2 Gen. 2002	M1 Gen. 2002	M2 Gen. 2003	M1 Gen. 2001	M2 Gen. 2002	M1 Gen. 2002	M2 Gen. 2003
A. caudatus	S.A	control	15.35	17.90	29.43	23.90	1.10	1.24	2.13	2.09
		1000 ppm	26.99	13.67	25.10	24.40	1.35	1.18	2.04	2.35
		2000 ppm	28.26	19.13	34.17	31.70	1.56	1.11	2.63	2.56
		3000 ppm	26.73	14.00	27.00	25.30	1.43	0.98	2.31	2.26
		4000 ppm	22.27	15.53	34.07	22.60	1.54	1.05	1.95	1.84
		5000 ppm	24.99	17.80	27.43	24.43	1.55	1.34	1.90	2.16
	Mean of S.A		24.10	16.34	29.53	25.38	1.42	1.15	2.16	2.21
	D.E.S	control	16.26	16.90	22.77	22.27	1.40	1.49	1.70	2.23
		1000 ppm	21.23	20.97	24.13	22.67	1.69	1.76	2.17	1.92
		2000 ppm	26.70	14.93	30.83	27.37	1.98	1.29	2.40	2.01
		3000 ppm	27.84	17.97	27.27	22.03	1.55	1.22	1.46	2.03
		4000 ppm	22.88	17.33	29.80	28.47	1.56	1.13	2.49	2.33
		5000 ppm	22.27	20.00	23.43	13.7	1.80	1.15	2.10	2.01
	Mean of D.E.S		22.87	18.02	26.37	22.75	1.66	1.34	2.06	2.09
Mean of A. caudatus			23.48	17.18	27.95	24.07	1.54	1.25	2.11	2.15
A. hypochondriacus	S.A	control	5.28	12.17	8.77	8.47	1.24	2.83	1.85	1.83
		1000 ppm	4.02	12.67	8.03	7.73	1.97	2.21	1.88	1.87
		2000 ppm	4.22	11.43	11.10	8.03	1.56	2.27	2.77	2.24
		3000 ppm	3.33	17.70	7.77	8.83	1.68	3.32	2.55	2.12
		4000 ppm	4.51	16.97	10.50	7.97	1.44	3.20	1.95	1.88
		5000 ppm	3.97	11.97	8.70	7.70	1.62	2.99	2.63	2.36
	Mean of S.A		4.22	13.82	9.14	8.12	1.59	2.80	2.26	2.05
	D.E.S	control	4.62	10.73	9.20	8.53	1.27	2.35	1.83	1.88
		1000 ppm	5.71	13.20	15.83	8.40	1.58	2.64	2.56	2.52
		2000 ppm	5.36	16.33	13.63	9.03	1.24	2.91	2.49	2.60
		3000 ppm	5.08	12.83	7.73	7.63	0.99	2.30	2.05	2.09
		4000 ppm	6.22	13.37	11.90	11.57	1.22	2.90	2.48	2.32
		5000 ppm	4.70	12.70	9.27	9.87	1.11	3.08	2.50	2.62
	Mean of D.E.S		5.28	13.19	11.26	9.17	1.24	2.70	2.32	2.34
Mean of A. hypochondriacus			4.75	13.51	10.20	8.65	1.42	2.75	2.29	2.19
L.S.D 0.05 for Sp.			1.89	N.S	7.17	3.71	N.S	0.6	N.S	N.S
Mean of Mutagens		S.A	14.16	15.08	19.34	16.76	1.51	1.98	2.13	2.21
		D.E.S	14.07	15.61	18.82	15.96	1.45	2.02	2.21	2.19
L.S.D 0.05 for Mut.			N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Mean of concentrations		control	10.38	14.43	17.54	15.79	1.25	1.98	2.01	1.88
		1000 ppm	14.49	15.13	18.28	15.80	1.65	1.95	2.17	2.15
		2000 ppm	16.14	15.46	22.43	19.03	1.59	1.89	2.35	2.57
		3000 ppm	15.75	15.63	17.44	15.95	1.41	1.96	2.13	2.09
		4000 ppm	13.97	15.80	21.57	17.65	1.44	2.07	2.09	2.22
		5000 ppm	13.98	15.62	17.21	13.93	1.52	2.14	2.29	2.28
L.S.D 0.05 for Conc.			2.86	N.S	N.S	N.S	0.22	N.S	0.32	N.S

In the M2–generation of *A. caudatus*, the least inflorescence diameters were obtained at the concentrations of 3000 (0.98 cm), 4000 ppm. SA (1.84 cm) and 1000 ppm. DES (1.92 cm) and 4000 ppm DES (1,13 cm), while the greatest ones were obtained at 5000 (1.34 cm.), 2000 ppm. SA (2.56 cm) and 1000 (1.76 cm) ,4000 ppm. DES (2.33 cm). As for *A. hypochondriacus*, the least inflorescence diameters were obtained at the doses of 1000 (2.21 cm), zero SA (1.83 cm) and 3000 (2.30 cm), zero DES (1.88 cm), while the largest ones were found at 3000 (3.32 cm), 5000 ppm. SA (2.05 cm) and 5000 ppm. DES (3.08 and 2.62 cm) in the first and second seasons, respectively.

The comparison between the two species, data indicated that *A. hypochondriacus* had greater inflorescence diameters than *A. caudatus* in both generations. The comparison between the two mutagens, data showed that SA had thicker inflorescence diameters than DES, in M1 only. In the M1- and M2- generations the comparison between the different means of concentrations, indicated that the maximum average inflorescence diameter was produced by 2000 ppm, while the minimum average inflorescence diameter was detected in the control.

Data indicated that there were significant effects on the inflorescence diameter among the mutagen concentrations in M1- generation during the two seasons. Stimulation and reduction in inflorescence diameter could be attributed to the effect of low and high concentrations of chemical mutagens on the cell number and length. Cell number and length may be altered in the inflorescence as a result of chemical treatment. Large inflorescence had larger florets with an increase in all number and / or cell size. Small inflorescence had smaller florets with a decrease in cell number and / or cell size (Bidwell, 1974).

These results seemed to agree with those reported by Neagu (1974) on sunflower; Al- Saheal and Gamil (1982) on wheat; Krivitskii *et al.* (1989) on *Amaranthus cruentus* and Vandana (1994) on *Vicia faba.*

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الملخص العربي

تأثير المطفران الكيماويان (أزايد الصوديوم وثنائى إيثايل السلفات) على نوعين من الأمرنتس *Amaranthus caudatus* L. و *A. hypochondriacus* L.

I - النمو الخضرى والإزهار

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قسم الزهور ونباتات الزينة وتنسيق الحدائق – كلية الزراعة – جامعة الإسكندرية

أجرى هذا البحث في حدائق أبحاث الزهور ونباتات الزينة بمحطة البحوث الزراعية التابعة لكلية الزراعة جامعة الإسكندرية خلال الموسمين ٢٠٠١/ ٢٠٠٢ و٢٠٠٢/٢٠٠٣ . وقد أختير لهذه الدراسة نوعين من نبات الأمارانتس *Amaranthus* أحدهما النوع *A. caudatus*, L. والثاني. *A. hypochondriacus*L. . و كان الهدف الرئيسي من البحث هو دراسة تأثير التركيزات المختلفة من مادتي الصوديوم أزايد (SA) والداى إيثيل سلفيت (DES) المطفرتان على النمو الخضر ى والإزهار مما قد يزيد من القيمة التنسيقية للنبات.

وقد عوملت البذور تحت الدراسة بالتركيزات الآتية من المطفران SA و DES : صفر (مقارنة) و ١٠٠٠ و ٢٠٠٠ و٣٠٠٠ و ٤٠٠٠ و٥٠٠٠ جزء في المليون ، وذلك فى ٣ / ٤ / ٢٠٠١ بالنسبة للموسم الأول و١ / ٤ / ٢٠٠٢ بالنسبة للموسم الثاني.

وكان تصميم التجربة فى صورة قطع عديدة الإنشقاق فى ثلاث مكررات ضمت كل مكررة نوعين ومطفران وستة تركيزات (٢x٢x٦ = ٢٤ معاملة). وكان عامل القطع الكبير هو نوع النبات وعامل القطع الصغير هو المطفر وعامل القطع تحت الصغير هو التركيز وخصص لكل معاملة ١٥٠ بذرة لكل نوع ومطفر مقسمة على ثلاث مكررات بمعدل ٥٠ بذرة لكل مكررة.

ويمكن تلخيص النتائج التي تم الحصول عليها فيما يلي :

١. أدت المعاملة بالتركيزات المختلفة من مادتي الصوديوم أزايد (SA) والداى إيثيل سلفيت (DES) المطفرتان إلي زيادة فى نسبة إنبات البذور و إرتفاع النبات و عدد الفروع و قطر الساق و عدد الأوراق و مساحة الورقة فى الموسم الأول و الثانى بينما لم يكن هناك تأثير معنوي بين الصنفين ولا في التفاعل بين العوامل الثلاثة في كل من الموسمين .

٢. بالنسبة للنوع *A. caudatus* أدت المعاملة بالتركيز ١٠٠٠و٣٠٠٠ جزء في المليون من المطفر SA إلي أعلى زيادة فى محتوى صبغة الأنثوسيانين فى الموسم الأول و التركيز ٣٠٠٠ جزء في المليون فى الموسم الثانى بينما كانت أعلى محتوى صبغة الأنثوسيانين عند إستخدام المطفر DES بتركيز ٢٠٠٠ جزء في المليون فى الموسم الأول و٤٠٠٠ و٢٠٠٠ جزء في المليون فى الموسم الثانى .لم يكن هناك فروق معنوية بين المطفرين والتركيزات والتفاعل بينهم .

٣. بالنسبة للنوع *A. hypochondriacus* أدت المعاملة بالتركيز ٥٠٠٠ جزء في المليون من المطفر SA إلي أعلى زيادة فى نسبة صبغة الكلوروفيل فى الموسم الأول و التركيزان صفر و ٢٠٠٠ جزء في المليون فى الموسم الثانى – بينما كانت أعلى نسبة صبغة الكلوروفيل عند إستخدام المطفر DES بتركيز ٣٠٠٠ جزء في المليون فى كلا الموسمين .لم يكن هناك فروق معنوية بين المطفرين والتركيزات والتفاعل بينهم .

٤. أدت المعاملة بالتركيزات المختلفة من مادتي الصوديوم أزايد (SA) والداى إيثيل سلفيت (DES) المطفرتان إلي زيادة الوزن الرطب والجاف. كانت هناك فروق معنوية بين النوعين في كل من الموسمين – بينما كانت الفروق غير معنوية بين المطفرين والتركيزات والتفاعل بينهم في كل من الموسمين .

٥. بالنسبة لعدد الأيام حتى بدء التزهير، فقد أدى إستخدام كلا المطفرين إلى تأخير الإزهار فى كلا النوعين وقد كانت هناك فروقا معنوية بين النوعين والمطفرين والتركيزات والتفاعل بينهم في كلا الموسمين. بينما أدى إستخدام كلا المطفرين إلى زيادة عدد الأزهار وزيادة في قطر النورة وكانت الفروق غير معنوية بين النوعين وبين المطفرين وبين التركيزات والتفاعل بينهم في الموسمين.