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Effect of Different Chemical Additives on Growth and Flowering of African Marigold (*Tagetes erecta* L.) Grown under Cadmium Stress

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Abstract: This study was carried out at the experimental field of the Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, during the two successive seasons of 2012 and 2013. The aim of this study was to investigate the possibility of reducing the harmful effect of cadmium soil pollution on the growth and flowering of *Tagetes erecta* (Marigold) plants by the addition of nickel, salicylic acid and Fe+EDTA to the soil. Plants were grown in 20cm pots filled with clay + sand (1:1,v/v) and were treated twice with cadmium acetate [$(CH_3COO)_2Cd.2H_2O$] as a soil drench at 0, 2.5, 7.5 and 12.5 mg/pot, in addition to three different chemicals(nickel sulphate [$NiSO_4.H_2O$]) as a soil drench at 3 and 6 mg/pot, EDTA+Fe Na [$C_{10}H_{12}N_2O_8.FeNa$] as a foliar spray at 15 and 30 ppm and salicylic acid [$C_7H_6O_3$] as a foliar spray at 50 and 100 ppm). Control plants received the Cd treatments only. The recorded results showed that Cd acetate at12.5 mg/pot gave the lowest values for the studied vegetative growth and flowering characteristics. In most cases, the different chemical additives (except salicylic acid at 100 ppm)also decreased the number of branches and flower heads per plant, as well as the fresh and dry weights of shoots and flower heads. From the results of this study, it was concluded that salicylic acid can be applied at 100 ppm in the nursery or the production field to increase yield of *Tagetes erecta* (Marigold) under cadmium stress.

Key words: *Tagetes erecta* · African marigold · Salicylic acid · EDTA+Fe · Cadmium acetate · Nickel sulphate · Chemical additives

INTRODUCTION

African marigold (*Tagetes erecta* L.) belongs to the Asteraceae family and is native to Mexico and Central America. It is a herbaceous plant with aromatic, pinnately divided leaves and is usually used as a bedding plants, or for the production of cut flowers. The flowers can be used as a coloring agent in poultry feed to obtain yellow egg yolks [1].

The increasing use of wide varieties of heavy metals in both the industrial and agricultural sectors has caused a serious concern of environmental pollution. At high concentrations, heavy metals cause severe damage to plants [2 -7]. Cadmium (Cd)is a highly toxic pollutant released into the environment by both anthropogenic and natural sources. Its presence in the soil, including agricultural lands, is considered a serious environmental issue, mainly because of its entry in the human food chain,and its dangerous effects on living organisms. Although Cd is not essential for plant growth, but it is readily taken up by roots and accumulated in plant tissues at high levels [8]. Excess of cadmium causes a number of toxic symptoms to the plants,viz. growth retardation, inhibition of photosynthesis, induction and inhibition of enzymes, altered stomatal action, efflux of cations and generation of free radicals [9]. Cadmium has been shown to affect various aspects of metabolism in different plant systems [10].

There are several methods that can limit access of heavy metals into the plants, e.g. introducing organic substances to the soil, some chemical treatments, or even liming.Thus, testing the effectiveness of such chemical treatments is a matter of urgency, in order to help in the development of technologies to remediate the Cd contaminated soils.The selected chemicals should have low environmental impact but high efficiency [11]. Strong metal chelating, neutral salts and strong acids have been used, especially ethylene diamine tetra acetic

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acid (EDTA),which can be an efficient means to remove Cd from contaminated soils, although its extraction efficiency depends on many factors, such as liability of heavy metals in soil, the strength of EDTA, electrolytes, pH and soil matrix [12 - 15]. Also, the chelating organic acids are able to dislodge the exchangeable fractions of heavy metals; likewise other chelating compounds such as citric acid and salicylic acid [16,17].

Cd is an element of group IIB in the periodic table and its atomic number is 48. It shows chemical similarity with the other elements of group IIB, especially with nickel (Ni). Cd and Ni are elements having similar geochemical and environmental properties; their chemical similarity can lead to competition between them during plant uptake and transport from roots to the aerial parts [18].

Therefore, this study was conducted to investigate the effect of different rates of chemical treatments, using additives such as a nickel, EDTA+Fe or salicylic acid, on the vegetative growth and flowering of marigold (*Tagetes erecta)* plants grown under Cd stress. The information provided by this study may help in the success of reducing the harmful effects of cadmium.

MATERIAL AND METHODS

This study was carried out at the experimental nursery of the Ornamental Horticulture Department, Faculty of Agriculture, Cairo University during the two successive years of 2012 and 2013. The aim of this study was to investigate the feasibility of using some chemical additive treatments(such as nickel, EDTA+Fe and salicylic acid)to reduce the harmful effects of cadmium on the growth and flowering of *Tagetes erecta* plants.

On the 5th of March, 2012 and 2013, F1 seeds of marigold (*Tagetes erecta* L.),obtained from the Egyptian Co. (Shaaban El-Korma, El-Gomhoreya St., Cairo), were sown individually in plastic pots (20-cm in diameter) filled with a clay+sand mixture (1:1, v/v).The physical and chemical characteristics of the sand and clay loam used in preparing the potting mixture are shown in Table (1). The pots were placed in a sunny area. Thick polyethylene sheets were spread underneath the pots to prevent the roots from penetrating into the soil.

In both seasons, the established plants were treated with cadmium acetate [$(CH_3COO)_2Cd.2H_2O$] as a soil drench at the rate of0, 2.5, 7.5 and 12.5 mg/pot and supplied separately with different chemical additives, including nickel sulphate [$NiSO_4.H_2O$] as a soil drench at the rate of3 and 6 mg/pot,salicylic acid [$C_7H_6O_3$] as a foliar spray at the rate of 50 and 100 ppm and EDTA+FeNa [$C_{10}H_{12}N_2O_8.FeNa$] as a foliar spray at the rate of 15 and 30 ppm. The cadmium and chemical additive treatments were applied twice,onthe 5th of April and the 5th of May (in both seasons). Control plants were treated with cadmium acetate [$(CH_3COO)_2Cd.2H_2O$] as a soil drench at the rate of 0, 2.5, 7.5 and 12.5 mg/pot,but were not treated with any chemical additives.

Common cultural practices were followed, including regular watering, hand picking of weeds, as well as the recommended NPK fertilization using ammonium sulphate (20.5%N), triple calcium super phosphate (46%P_2O_5) and potassium sulphate (48%K_2O)[19]. Fertilization, at the ratio of 6.83:15.33:16, was applied twice in the soil (on 12thApril 2012 and 13th May 2013 in the first and second seasons, respectively), at the rate of 0.5 g/pot.

The layout of the experiment was a randomized complete blocks design, with 28 treatments [4 different cadmium concentrations X 7 chemical additive treatments),including the control and 5 blocks (replicates), each consisting of 56 plants (2 plants/treatment).

On the 28th of June 2012 and 2013 (in the first and second seasons, respectively), the experiment was terminated and data were recorded on the different vegetative growth characteristics [number of branches per plant, fresh and dry weights of shoots (stems+ leaves)]. Also, data were recorded on the flowering characteristics including the number of flower heads per plant, as well as the fresh and dry weights of flower heads per plant.

The recorded data were statistically analyzed. An analysis of variance (ANOVA) was carried out and the means were compared using the Least Significant Difference (L.S.D.) test at the 0.05 level [20].

Table 1: Physical and chemical characteristics of the sand and clay loam used for growing *Tageteserecta*plants during the 2012 and 2013 seasons.

Physical characteristics						Sand					Clay loam
CEC (meq/100g)						5.30					31.40
Field capacity (% v)						16.00					47.30
Chemical characteristics											
Organic matter (%)	pH	EC (dS/m)	N (ppm)	P (ppm)	K (ppm)	Mg (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cd (ppm)	Ni (ppm)
Sand											
1.5	7.1	2.25	18	17	211	24.60	2.90	2.80	24.60	0.032	0.01
Clay loam											
2.4	7.9	7.67	40.52	20.25	239	36.80	2.10	3.10	36.80	0.01	0.20

Table 2: Effect of cadmium rates in combination with nickel, salicylic acid or EDTA+Fe treatments on the number of branches/plant of African marigold (*Tageteserecta*) during the 2012 and 2013 seasons

	Number of branches per plant							
	Chemical additives (CA)							
		Nickel		Salicylic acid		EDTA + Fe		
Cadmium acetate rate (Cd)	Control	3mg/pot	6mg/pot	50 ppm	100ppm	15 ppm	30ppm	Mean (Cd)
1st Season (2012)								
0 mg/pot (Control)	12.40	6.80	6.00	8.40	11.60	7.20	7.80	8.60
2.5 mg/pot	4.20	3.60	3.00	6.20	8.00	5.00	6.40	5.20
7.5 mg/pot	4.00	3.20	3.80	4.00	4.20	2.40	2.00	3.37
12.5 mg/pot	1.40	1.20	1.20	2.00	2.20	1.00	1.00	1.43
Mean (CA)	5.50	3.70	3.50	5.15	6.50	3.90	4.30	----
LSD (0.05)		Cd: 0.56		CA: 0.73		Cd x CA: 1.47		
2nd Season (2013)								
0 mg/pot (Control)	20.60	8.00	6.20	10.00	14.40	8.60	9.60	11.06
2.5 mg/pot	5.00	5.20	6.20	8.60	10.80	6.80	7.20	7.11
7.5 mg/pot	3.80	3.00	3.40	4.40	5.20	3.20	3.40	3.77
12.5 mg/pot	1.00	1.80	2.00	3.00	3.80	1.40	1.20	2.03
Mean (CA)	7.60	4.50	4.45	6.50	8.55	5.00	5.35	----
LSD (0.05)		Cd: 0.54		CA: 0.72		Cd x CA: 1.44		

RESULTS AND DISCUSSION

Vegetative Growth

Number of Branches per Plant: Data presented in Table (2) show that the number of branches per plant was significantly affected by the cadmium acetate concentration in which the plants were grown. In both seasons, the lowest numbers of branches (1.43 and 2.03 branches/plant in the first and second seasons, respectively) were formed on plants receiving the highest rate of cadmium acetate (12.5 mg/pot). The enhancement of plant growth (in terms of number of branches per plants) as a result of using a cadmium-free soil was clear in both seasons, with untreated plants forming significantly more branches (8.60 and 11.06branches/plant in the first and second seasons, respectively), compared to plants that received any of the cadmium acetate treatments. These results are in agreement with the findings of several researchers who reported that cadmium stress decreased the number of branches in different ornamental plant species, such as *Mentha piperita, Mentha arvensis*, *Catharanthus roses*, *Salvia splendens*, *Tagetes erecta* and *Abelmoschus manihot* and *Tagetes erecta* [21-24].

The application of chemical additives also had a significant effect on the number of branches formed by *Tagetes erecta* plants. From the recorded results (Table 2), it is clear that salicylic acid gave generally better branching of *Tagetes erecta* plants, compared to nickel or EDTA+Fe. In both seasons, plants receiving salicylic acid at 100 ppm gave significantly more branches/plant (with mean values of 6.50 and 8.55 branches/plant in the first and second seasons, respectively) than the control, or plants receiving any other chemical additive treatment. On the other hand, application of any rate of nickel or EDTA+Fe caused a significant reduction in the mean number of branches/plant, compared to the control. In most cases, no significant differences were recorded between the mean values obtained as a result of using nickel (at 3 or 6 mg/pot) or EDTA+Fe (especially at 15 ppm).

Regarding the interaction between the effects of cadmium stress and the chemical additive treatments on the number of branches per plant, the results recorded in both seasons (Table 2) show that, the highest number of branches (12.40 and 20.60 branches/plant in the first and second seasons, respectively) was obtained on plants that received no cadmium acetate or chemical additives treatments (control), followed by plants that only received salicylic acid at 100 ppm (with 11.60 and 14.40 branches/plant in the two seasons, respectively). On the other hand, the lowest number of branches (1.00 branch/plant) was formed on plants that received cadmium acetate at 12.5 mg/pot, plus EDTA+Fe at 15 or 30 ppm (in the first season), or with no chemical additives (in the second season).

The results recorded in the two seasons also show that, when the plants received no cadmium acetate treatment, application of the different chemical additive treatments significantly decreased the number of branches/plant, except in plants treated with salicylic acid at 100 ppm, which had insignificantly fewer branches (11.60 branches/plant) than the control (which had 12.40 branches/plant). However, when *Tagetes erecta* plants were treated with cadmium acetate at 2.5, 7.5 or 12.5 mg/pot, the adverse effect of Cd stress on the number of branches was generally reduced by the application of salicylic acid, especially when added at the high rate (100 ppm). This treatment (salicylic acid at 100 ppm) gave the highest number of branches formed under Cd stress conditions, with values of 8.00, 4.20 and 2.20 branches/plant at Cd acetate levels of 2.5, 7.5 and 12.5 mg/pot, respectively. A similar general trend was obtained in the second season, with plants receiving salicylic acid forming the highest number of branches under Cd stress conditions (10.80, 5.20 and 3.80 branches/plant at Cd acetate levels of 2.5, 7.5 and 12.5 mg/pot, respectively). It is also noted that at the low Cd acetate level (2.5 mg/pot), the addition of EDTA+Fe at 15 or 30 ppm also caused some improvement in the branching of *Tagetes erecta* plants (in both seasons) compared to the control, but at higher levels of Cd stress (7.5 or 12.5 mg/pot), the EDTA+Fe treatments did not have any clear effect. The positive effect of salicylic acid on branching under Cd stress conditions are in agreement with the findings of several researchers, who reported that chemical additives could be used to increase the number of branches formed by different ornamental plant species under cadmium stress, such as *Tagetes erecta*, *Coriandrum sativum*, *Pelargonium hortorum* and *Helianthus annuus* [25-28].

Plant Shoots (Stems+Leaves) Fresh and Dry Weights: The data presented in Tables (3) and (4) show that, in both seasons, raising the Cd acetate rate from 0 mg/pot (control) to 2.5, 7.5 or 12.5 mg/pot caused steady significant reductions in the mean fresh and dry weights of marigold (*Tagetes erecta*) plants.Similar reductions in plant fresh and dry weights as a result of cadmium stress have been reported in a number of ornamental plant species, including *Silene vulgaris*, *Viola baoshanensis* and *Tagetes erecta* [29-31]. This adverse effect of Cd acetate treatments on vegetative growth may attributed to the sensitivity to cadmium stress, which leads to inhibition and growth abnormalities in many plant species, including reduction of shoots elongation, rolling of leaves and chlorosis [32, 33]. These symptoms were attributed to disordered division and abnormal enlargement of the epidermal and cortical cell layers in the apical region. The changes in the leaf included alterations in chloroplast ultrastructure, low contents of chlorophylls, which caused chlorosis and restricted photosynthetic activity [34-37].

Table 3: Effect of cadmium rates in combination with nickel, salicylic acid or EDTA+Fe treatments on fresh weight of shoots (g. /plant) of African marigold (*Tageteserecta*) during the 2012 and 2013 seasons.

Fresh weight of shoots (gm/plant)								
	Chemical additives (CA)							
		Nickel		Salicylic acid		EDTA + Fe		
Cadmium acetate rate (Cd)	Control	3mg/pot	6mg/pot	50 ppm	100ppm	15 ppm	30ppm	Mean (Cd)
				1st Season (2012)				
0 mg/pot (Control)	90.82	68.91	58.06	76.86	85.77	65.21	68.97	73.51
2.5 mg/pot	52.15	55.44	62.48	63.99	74.66	52.06	48.25	58.43
7.5 mg/pot	32.66	31.04	35.82	38.67	43.13	33.19	33.82	35.48
12.5 mg/pot	19.02	17.38	21.26	27.82	30.12	14.18	10.91	20.10
Mean (CA)	48.66	43.19	44.41	51.83	58.42	41.16	40.49	----
LSD (0.05)		Cd: 2.26		CA: 2.99		Cd x CA: 5.98		
				2nd Season (2013)				
0 mg/pot (Control)	78.52	48.52	41.69	57.68	69.33	47.16	51.07	56.28
2.5 mg/pot	29.48	34.59	37.62	42.99	49.29	32.89	35.23	37.44
7.5 mg/pot	22.67	21.04	22.91	27.20	32.42	18.37	19.55	23.45
12.5 mg/pot	10.96	15.82	16.98	18.60	22.98	13.25	11.32	15.70
Mean (CA)	35.41	29.99	29.80	36.61	43.50	27.92	29.29	----
LSD (0.05)		Cd: 1.04		CA: 1.37		Cd x CA: 2.74		

Table 4: Effect of cadmium rates in combination with Nickel, Salicylic acid or EDTA+Fe treatments on dry weight of shoots (g. /plant) of African marigold (*Tageteserecta*) during the 2012 and 2013 seasons

Dry weight of shoots (gm/plant)								
	Chemical additives (CA)							
		Nickel		Salicylic acid		EDTA + Fe		
Cadmium acetate rate (Cd)	Control	3mg/pot	6mg/pot	50 ppm	100ppm	15 ppm	30ppm	Mean (Cd)
1st Season (2012)								
0 mg/pot (Control)	20.08	14.57	12.32	15.79	20.82	13.61	15.15	16.05
2.5 mg/pot	12.14	12.82	14.00	14.99	17.30	11.83	13.55	13.80
7.5 mg/pot	6.82	6.80	7.19	8.46	9.16	6.98	7.82	7.60
12.5 mg/pot	3.42	4.45	4.71	5.19	6.57	3.15	3.39	4.41
Mean (CA)	10.61	9.66	9.55	11.11	13.46	8.89	9.98	----
LSD (0.05)		Cd: 0.92		CA: 1.22		Cd x CA: 2.43		
2nd Season (2013)								
0 mg/pot (Control)	21.78	13.47	11.57	15.92	19.16	13.21	14.21	15.62
2.5 mg/pot	8.30	9.77	10.62	12.22	13.52	9.40	10.08	10.56
7.5 mg/pot	6.36	5.94	6.46	7.69	9.22	5.21	5.52	6.63
12.5 mg/pot	3.07	4.44	4.77	5.20	6.42	3.79	3.47	4.45
Mean (CA)	9.88	8.41	8.36	10.26	12.08	7.90	8.32	----
LSD (0.05)		Cd: 0.29		CA: 0.38		Cd x CA: 0.76		

The chemical additive treatments also had a considerable effect on the plant fresh and dry weights. The data presented in Tables (3) and (4) show that, in both seasons, the highest mean plant fresh and dry weights were recorded in plants sprayed with the high salicylic acid concentration (100 ppm),whereas the lowest fresh and dry weights were those of plants sprayed with EDTA+Fe at 15 ppm (in most cases seasons).

The results recorded in the two seasons (Tables 3 and 4) also show that using the different combinations of cadmium acetate and chemical additive treatments caused considerable differences in plant fresh and dry weights. In most cases, the heaviest fresh and dry weights were obtained from plants that received no cadmium acetate or chemical additive treatments (control), followed by plants that received no cadmium acetate treatment but were sprayed with salicylic acid at 100 ppm.On the other hand, the lowest fresh weight was obtained from plants that received cadmium acetate at the rate of 12.5 mg/pot,in combination with EDTA+Fe at 30ppm (in the first season), or with no chemical additives (in the second season). Plant dry weight followed a generally similar trend, giving the lowest values in plants that were treated with cadmium acetate at the rate of 12.5 mg/pot in combination with EDTA+Fe at 15 or 30 ppm (in the first season), or with no chemical additives (in the second season).

It is also clear from the results recorded in the two seasons (Tables 3 and 4) that, in most cases, plants receiving the different cadmium acetate treatments in combination with salicylic acid (especially when sprayed at the concentration of 100 ppm) had significantly higher fresh and dry weights, compared to plants treated with cadmium acetate alone. The beneficial effect of salicylic acid in counteracting the toxic effect of cadmium on vegetative growth (in terms of branching, as well as plant fresh and dry weights) may be attributed to the role of salicylic acid as a potential growth regulator and a stabilizer for protection of cells against oxidative damage and photosynthesis inhibition caused by cadmium toxicity [32]. A similar positive effect of salicylic acid on growth in the presence of cadmium was reported by Metwally *et al*. [38], who found that exposure to cadmium reduced root and shoot length and fresh weight in barley seedlings and that salicylic acid treatment decreased cadmium toxicity. In another study on sunflower plants that were exposed to cadmium toxicity, similar results were attributed to the beneficial effect of salicylic acid on leaf lipid metabolism, probably in relation to chlorophyll synthesis, photosynthetic activity and carbon supply [39].

Flowering Characteristics

Number of Flowerheads per Plant: The data presented in Table (5) show that, in both seasons, the number of inflorescences on *Tagetes erecta* plants was significantly affected by the cadmium acetate concentration in which the plants were grown.In both seasons, the highest number of flower heads (8.23 and 7.83 flowerheads/plant in the first and second seasons, respectively) was formed on untreated plants.In contrast,

Table 5: Effect of cadmium rates in combination with Nickel, Salicylic acid or EDTA+Fe treatments on number of flowers-heads /plant of African marigold (*Tageteserecta*) during the 2012 and 2013 seasons.

	Number of flowerheads/plant							
	Chemical additives (CA)							
		Nickel		Salicylic acid		EDTA + Fe		
Cadmium acetate rate (Cd)	Control	3 mg/pot	6 mg/pot	50 ppm	100 ppm	15 ppm	30 ppm	Mean (Cd)
1st Season (2012)								
0 mg/pot (Control)	12.00	7.20	5.20	8.40	11.60	6.00	7.20	8.23
2.5 mg/pot	4.40	3.80	4.00	5.80	6.40	3.80	4.80	4.71
7.5 mg/pot	2.00	2.20	2.60	2.80	3.40	2.60	1.80	2.49
12.5 mg/pot	1.20	1.00	1.60	2.20	3.20	1.40	1.00	1.66
Mean (CA)	4.90	3.55	3.35	4.80	6.15	3.45	3.70	----
LSD (0.05)		Cd: 0.55		CA: 0.73		Cd x CA: 1.46		
2nd Season (2013)								
0 mg/pot (Control)	13.60	7.20	3.60	9.40	10.40	4.60	6.00	7.83
2.5 mg/pot	3.00	2.00	2.60	4.00	5.00	2.40	3.20	3.17
7.5 mg/pot	1.20	1.40	1.40	1.60	2.00	1.60	1.60	1.54
12.5 mg/pot	1.00	1.20	1.00	1.60	1.80	1.20	1.60	1.34
Mean (CA)	4.70	2.95	2.15	4.15	4.80	2.45	3.10	----
LSD (0.05)		Cd: 0.70		CA: 0.93		Cd x CA: 1.85		

the lowest number of flower heads (1.66 and 1.34 flowerheads/plant in the first and second seasons, respectively) was formed on plants receiving the highest rate of cadmium acetate (12.5 mg/pot).In the second season, no significant difference was recorded between the number of flower heads formed on plants treated with cadmium acetate at 7.5 or 12.5 mg/pot (with 1.54 and 1.34 flower heads/plant, respectively). These results are in agreement with the findings of several researchers who reported that cadmium stress decreased the number of number of flower heads in different ornamental plant species, such as *Ligustrum vulgare, Vinca rosea*, *Salvia splendens*, *Tagetes erecta, Chrysanthemum indicum* and *Gladiolus grandiflorus* [40-42].

The application of chemical additives also had a significant effect on the number of flower heads formed by *Tagetes erecta* plants. From the recorded results (Table 5), it is clear that salicylic acid gave generally better flowering of *Tagetes erecta* plants, compared to nickel or EDTA+Fe.In most cases, plants receiving salicylic acid at 100 ppm gave significantly more flower heads/plant (with mean values of 6.15 and 4.80 flower heads/plant in the first and second seasons, respectively) than the control, or plants receiving any other chemical additive treatments. Only two exceptions to this general trend were recorded in the second season, with plants receiving (salicylic acid at 100 ppm) giving insignificantly more flower heads/plant than control plants (which gave 4.70 flower heads/plant) or plants treated with salicylic acid at 50 ppm (with 4.15 flower heads/plant). On the other hand, application of any rate of nickel or EDTA+Fe caused a significant reduction in the mean number of flower heads/plant, compared to the control. In most cases, no significant differences were recorded between the mean values obtained as a result of using nickel (at 3 or 6 mg/pot) or EDTA+Fe (especially at 15 ppm).

Regarding the interaction between the effects of cadmium stress and the chemical additive treatments on the number of flower heads per plant, the results presented in Table (5) show that in both seasons, the highest number of flower heads (12.00 and 13.60 flowerheads/plant in the first and second seasons, respectively) were obtained on plants that received no cadmium acetate or chemical additive treatments (control), followed by plants that only received salicylic acid at 100 ppm (with 11.60 and 10.40 flowerheads/plant in the two seasons, respectively). On the other hand, the lowest number of flower heads recorded in the first season (1.00 flowerhead/plant) was formed on plants that received cadmium acetate at 12.5 mg/pot, plus EDTA+Fe at 30 ppm or nickel at 3mg/pot, whereas the lowest value in the second season (1.00 flower head/plant) was formed on plants that received cadmium acetate at 12.5 mg/pot, either alone or in combination with nickel at 6mg/pot. The results recorded in the two seasons also show that when the plants received no cadmium acetate treatment, application of the different chemical additive treatments significantly decreased the number of flower heads/plant (in most cases).Only one exception to this general trend was recorded in the first season, with plants receiving

Table 6: Effect of cadmium acetate rates in combination with nickel, salicylic acid or EDTA+Fe treatments on fresh weights of flowersheads (g/plant) of African marigold (*Tageteserecta*) during the 2012 and 2013 seasons

Fresh weight of flower heads (g/plant)								
	Chemical additives (CA)							
		Nickel		Salicylic acid		EDTA + Fe		
Cadmium acetate rate (Cd)	Control	3 mg/pot	6 mg/pot	50 ppm	100 ppm	15 ppm	30 ppm	Mean (Cd)
1st Season (2012)								
0 mg/pot (Control)	12.60	6.73	4.32	7.77	9.90	5.41	7.19	7.70
2.5 mg/pot	3.05	2.94	3.41	4.49	5.60	3.11	4.07	3.81
7.5 mg/pot	1.04	1.33	1.76	2.06	2.58	1.84	1.83	1.78
12.5 mg/pot	1.01	1.04	1.39	1.54	2.09	1.24	1.50	1.40
Mean (CA)	4.42	3.01	2.72	3.97	5.04	2.90	3.65	----
LSD (0.05)		Cd: 0.25		CA: 0.32		Cd x CA: 0.65		
2nd Season (2013)								
0 mg/pot (Control)	14.76	9.62	8.22	10.84	12.16	8.89	9.23	14.76
2.5 mg/pot	5.16	4.57	5.09	6.36	7.30	5.39	5.99	5.16
7.5 mg/pot	2.16	2.29	2.76	3.00	4.07	3.03	3.17	2.16
12.5 mg/pot	1.00	1.05	1.19	1.33	1.76	1.19	1.47	1.00
Mean (CA)	5.77	4.38	4.31	5.38	6.33	4.63	4.96	----
LSD (0.05)		Cd: 0.31		CA: 0.41		Cd x CA: 0.81		

salicylic acid at 100 ppm forming insignificantly fewer flower heads (11.60 flower heads/plant) than the control (which had 12.00 flower heads/plant).On the other hand, when *Tagetes erecta* plants were treated with cadmium acetate at 2.5, 7.5 or 12.5 mg/pot, the adverse effect of Cd stress on the number of flower-heads was generally reduced by the application of salicylic acid, especially when added at the high rate (100 ppm). In the first season, this treatment (salicylic acid at 100 ppm) gave the highest number of flower-heads formed under Cd stress conditions, with values of 6.40, 3.40 and 3.20 flower heads/plant at Cd acetate levels of 2.5, 7.5 and 12.5 mg/pot, respectively. A similar general trend was obtained in the second season, with plants receiving salicylic acid at 100 ppm forming the highest number of flower heads under Cd stress conditions (5.00, 2.00 and 1.80 flower heads/plant at Cd acetate levels of 2.5, 7.5 and 12.5 mg/pot, respectively). It is also noted that at the low Cd acetate level (2.5 mg/pot), plants that also received EDTA+Fe at 30 ppm had a slightly (insignificantly) higher number of flower heads (in both seasons), compared to the control. The positive effect of salicylic acid on flowering under Cd stress conditions are in agreement with the findings of several researchers, who reported that chemical additives could be used to increase the number of flower heads formed by different ornamental plant species under cadmium stress, such as *Salvia sclarea*, *Tagetes erecta* and *Pelargonium hortorum* [43, 25, 27].

Fresh and Dry Weight of Flower heads: The data presented in Tables (6) and (7) show that, in both seasons, raising the Cd acetate rate from 0 mg/pot (control) to 2.5, 7.5 or 12.5 mg/pot caused steady significant reductions in the mean fresh and dry weights on flower heads of marigold (*Tagetes erecta*) plants. Similar reductions in plant fresh and dry weights as a result of cadmium stress have been reported in a number of ornamental plant species, including *Catharanthus roses*, *Tagetes erecta*, *Chrysanthemum indicum* and *Gladiolus grandiflorus* and six marigold cultivars [31, 44, 42].

The chemical additive treatments also had a considerable effect on the fresh and dry weights of the flower heads. The data presented in Tables (6) and (7) show that in both seasons, the highest mean fresh and dry weights of flower heads were recorded in plants sprayed with the high salicylic acid concentration (100 ppm). On the other hand, the lowest mean fresh and dry weights recorded in the first season were those of plants treated with nickel at 6mg/pot, whereas the lowest values recorded in the second season were those of plants treated with nickel at 6 mg/pot.

The results recorded in the two seasons (Tables 6 and 7) also show that using the different combination of cadmium acetate and chemical additive treatments caused considerable differences in fresh and dry weights of flower heads. In both seasons, the heaviest fresh and dry weights were obtained from plants that received no

Table 7: Effect of cadmium rates in combination with nickel, salicylic acid or EDTA+Fe treatments on dry weights of flowers-heads (g/plant) of African marigold (*Tageteserecta*) during the 2012 and 2013 seasons.

	Dry weight of flower heads (g/plant)							
	Chemical additives (CA)							
		Nickel		Salicylic acid		EDTA + Fe		
Cadmium acetate rate (Cd)	Control	3 mg/pot	6 mg/pot	50 ppm	100 ppm	15 ppm	30 ppm	Mean (Cd)
1st Season (2012)								
0 mg/pot (Control)	5.79	3.74	2.60	4.28	5.05	3.11	3.45	4.00
2.5 mg/pot	1.57	1.99	2.28	2.90	3.20	2.08	2.36	2.34
7.5 mg/pot	0.88	0.95	1.12	1.22	1.40	1.05	1.11	1.10
12.5 mg/pot	0.57	0.67	0.93	1.10	1.20	0.88	0.94	0.90
Mean (CA)	2.20	1.84	1.73	2.38	2.71	1.78	1.96	----
LSD (0.05)		Cd: 0.18		CA: 0.16		Cd x CA: 0.31		
2nd Season (2013)								
0 mg/pot (Control)	5.14	3.36	2.87	3.78	4.24	3.10	3.22	3.67
2.5 mg/pot	1.80	1.59	1.77	2.22	2.54	1.88	2.09	1.99
7.5 mg/pot	0.75	0.80	0.96	1.11	1.42	1.06	1.11	1.03
12.5 mg/pot	0.35	0.37	0.42	0.46	0.72	0.42	0.51	0.46
Mean (CA)	2.01	1.53	1.51	1.89	2.23	1.61	1.73	----
LSD (0.05)		Cd: 0.11		CA: 0.15		Cd x CA: 0.29		

cadmium acetate or chemical additive treatments (control), followed by plants that received no cadmium acetate treatment but were sprayed with salicylic acid at 100 ppm. On the other hand, the lowest fresh weights recorded in the two seasons (1.01 and 1.00 g/plant in the first and second seasons, respectively) were obtained from plants that were treated with cadmium acetate at the rate of 12.5 mg/pot, with no chemical additives. The dry weight of flower heads followed a generally similar trend, giving the lowest values (0.57 and 0.35 g/plant in the two seasons, respectively) in plants that were treated with cadmium acetate at the rate of 12.5 mg/pot with no chemical additives (control).

It is also clear from the results recorded in the two seasons (Tables 6 and 7) that under Cd stress conditions (i.e., with Cd acetate at 2.5, 7.5 or 12.5 mg/pot), applying the different chemical additive treatments generally increased the fresh and dry weight of flower heads, compared to those of plants treated with Cd acetate alone.Among the different chemicals that were tested, salicylic acid was the most effective one in this respect, especially when it was sprayed at the concentration of 100 ppm. In both seasons, plants receiving any rate of Cd acetate in addition to salicylic acid at 100 ppm gave heavier fresh and dry flower heads than those produced by plants receiving the Cd acetate treatments alone or in combination with any other chemical additive treatment.

CONCLUSION

The vegetative and flowering characteristics of Marigold (*Tagetes erecta*) were negatively affected by cadmium at any concentration (in both seasons), but using chemical additive treatments, especially salicylic acid at the rate 100 ppm, counteracted the adverse effects of cadmium stress.

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