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Growth Responses of the Medicinal Shrub *Calotropis procera* Ait. R. Br. to Magnetic Water

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IN THE PRESENT study we aimed to evaluate the effect of using magnetic water in irrigation of the wide spread medicinal and economic plant; *Calotropis procera*, throughout the cultivation of the target species in open protected area under the prevailing external climatic conditions of Taif, KSA. Periodic readings of the growth parameters in the seedling, juvenile, mature and flowering growth stages was carried out using magnetic and nonmagnetic water. Measurements of the chemical coposition (proteins, lipids, carbohydrates, fiber and ash), phytohormones (GA_3 and IAA), plant pigments (Chlorophyll a, and b, xanthophylls and carotene), and some enzyme activities of the target species (amylase, peroxidase and protease) were carried out by the end of the greenhouse experiment. The effect of magnetic water treatment to *C. procera* demonstrated significant stimulating effects on the growth criteria of treated plants as compared to control plants. The root-shoot (R:S) ratio for all treated *C. procera* plants either by magnetic or nonmagnetic water, in almost all growth stages except the seedling stage, was almost lower than one. Considering *C. procera* plants irrigated with either magnetic or nonmagnetic water during the juvenile growth stage, the allocation of leaves was the highest among the other plant organs recording maximum values amounting to 51.41, 62.74, 63.64 and 33.12% for control, T_1 (treatment 1), T_2 (treatment 2) and T_3 (treatment3) plant samples; respectively. Comparing values of water contents of different plants showed general increase in the following order: leaves> flowers> stem> root. The number of leaves in the flowering growth stage recorded 14.66, 22.34, 28.37 and 29.98 in *C. procera* plants referred control, T_1, T_2 and T_3; respectively. The relative growth rates (RGRs) of *C. procera* control plants is generally higher than that of *C. procera* irrigated plants with magnetic water especially in the case of the first and third growth stages. In most cases, magnetic water increased all element and metal contents of *C. procera* leaves as compared to those irrigated by nonmagnetic water, except for iron and calcium. The magnetic water stimulated the production of phytohormones and photosynthetic pigments as compared to the control. In addition, the current study proved that magnetic water increased the enzyme activity of amylase and decreased that of protease and Peroxidase.

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The present study recommended the use of magnetic water in irrigation of economic important species such as the edible and medicinal ones, including *C. procera*.

Keywords: Magnetic water, *Calotropis procera*, Growth parameters.

Calotropis is a small genus having 6 species of shrubs or small trees, distributed in tropical and subtropical Africa, Asia, and America (Ibrahim *et al.*, 2015).The medicinal invasive species *Calotropis procera* (Ait.) R. Br. (Asclepiadaceae), known as Apple of Sodom, Milkweed or Swallow-wort, is a small, hardly, pubescent, evergreen, erect and compact shrub, up to 4.5 m high, covered with cottony tomentum (Mittal and Ali, 2015). It is a widely growing plant and has been reported to possess numerous medicinal properties. Different parts as well as its latex have been used as emetic, purgative and anthelmintic. By virtue of its ability to contract smooth muscles of gastrointestinal tract it exhibits spasmogenic and carminative properties (Kumar *et al*., 2001; Patil *et al*., 2016).

In recent decades many researchers, such as Alimi *et al*., (2006), Maheshwari and Grewal (2009) and Chen *et al.*, (2011) have reported the effect of magnetic water treatment on vegetable crop yield. Pietruszewski (1993) reported an increase on seedling growth, seed vigour and crop yield when seeds were exposed to a magnetic field. Aladjadjiyan (2002) detected that exposure to magnetic field stimulated shoot development and led to increase of the germination, fresh weight and shoot length of maize plants. Yinan *et al.* (2005) published that the magnetic field pretreatment had a positive effect on cucumber seedlings, such as stimulating seedling growth and development. Farrag (2013) had studied the effect of magnetic water treatment on the allelopathic potentiality of *Heliotropium curassavicum* on germination and seedling growth of *Faba sativa*.

However, there is hardly any study reported, with valid scientific experiments, on the effects of magnetic water treatment on the growth of *C. procera* in Taif, KSA. Therefore, in this study we investigated the effects of irrigation with magnetic water on growth parameters, chemical analysis, plant hormones, plant pigments and some enzyme activities of the studied species.

Materials and Methods

Plant and soil materials

The seeds of the target species were obtained from naturally growing populations at Wadi Galil, Taif, about 5 km east of El-Mattar road (21º 18´ N and 40º 28´ E and altitude of 1593m). Plastic pots (18 cm diameter and 25 cm depth) were used. The soil was obtained from the field study site. The soil samples were air-dried and passed through 2-mm sieve to separate litter and gravel. The air-dried sieved soil was filled into the experimental pots (8 kg soil/pot).

Magnetic water

Magnetic water was obtained by passing distilled water through a pipe containing set-up of permanent magnets (Magnetic technologies L.L.C., Model A100, Russian technology, Made in Russia) and according to Alimi *et al*., 2006.

Experimental conditions and design

The experiment was conducted in an open greenhouse at Wadi Galil, under the external natural environmental conditions. The prevailing climatic conditions during the experimental period included temperature which ranged between a minimum of 12.8 ^{o}C in November to a maximum value of 34.4 ^{o}C in July. Relative humidity ranged between minimum of 23% in June to a maximum value of 55% in November.

Ten seeds were sown in every pot at depth of 1cm. Four application rates of irrigation water were used; control treatment by irrigation with 300ml (field capacity) nonmagnetic water (normal irrigation water), treatment one by irrigation with (200ml nonmagnetic water+100ml magnetic water), treatment two by irrigation with (100ml nonmagnetic water+200ml magnetic water) and treatment three by irrigation with (300ml magnetic water) during four different growth stages; (seedling) = 21 days after sowing, (Juvenile) = 45 days, (mature) = 90 days and (flowering) = 180 days. Irrigation carried out twice a week, treatments were referred as Control, T1, T2 and T3; respectively. Five replicates were used for each treatment. Three of these replicates were harvested for measuring the growth criteria of the target species during the different above mentioned growth stages. Seedling emergence was monitored daily. After the seedling emergence ceased, seedlings were thinned to the most similar healthy five individuals per pot. All pots were watered regularly and equally when needed. The amount of water per pot was adjusted to avoid leaching out.

Harvest and measurements

Plant materials were harvested and data gathered at the four growth stages for the studied species. At each harvest stage, whole pot of each treatment was gently inverted and whole plants harvested individually by carefully clearing the soil with pressurized tap water. The growth criteria measurements included root depth, shoot height, leaf area, number of leaves and flowers. The whole plant was then divided into separate organs; roots, stems, leaves, and reproductive organs (flowers), and oven dried at 75 ^{0}C until constant weight. Dry phytomass was recorded for each organ. Five replicates were used for every measurement.

Root/shoot ratios, percent dry matter allocation and growth parameters including Relative Growth Rate (RGR), Net Assimilation Rate (NAR) and Leaf Area Ratio (LAR) were calculated according to Hegazy *et al*., (2001) by using the following equations: The RGR was calculated as g $g^{-1}day^{-1}$ over the time interval as: $RGR = (\ln W_2 - \ln W_1) / (t_2 - t_1)$ Where, W_1 and W_2 are weights at time t_1 and t_2, respectively.

The NAR was calculated as g mm^{-2} day^{-1} over the time interval as: NAR = {(ln A_2 – ln A_1) / (A_2 – A_1)} X {(W_2 – W_1) / (t_2 –t_1)}, and LAR calculated as mm^2 g^{-1} as follow: LAR= {(ln W_2 – ln W_1) / (lnA_2 – lnA_1)} X {(A_2 –A_1)/ (W_2 – W_1)} where, W_1, W_2 are weights and A_1, A_2 are leaf areas at time t_1 and t_2, respectively.

Water chemical analysis

Normal nonmagnetic water samples used in the current work were obtained from a near site from Wadi Galil, Taif province, KSA. Selected chemical, metal content and physical parameters (in three sequential samples) of the investigated nonmagnetic (normal water) and magnetic water samples were carried out according to the modified method described by Farrag (2013) and occurred in Water and Environment Research Institute (SWERI) which belongs to Agricultural Research Center (ARC), Giza, Egypt.

Soil chemical and mechanical analyses

Soil samples were taken from Al-Quaisem area at Wadi Galil, Taif. The soil then air-dried at room temperature for 15 days, and then ground to pass through 2mm nylon sieve. Exact one gram of soil samples were digested in 1:2:2 (v:v:v) HNO_3: HCl: $HClO_4$ mixture to obtain the total metal content. Concentration of the different metals in the soil samples were determined by inductively coupled plasma-atomic emission spectroscopy (ICP-Ultima (Z) version 5 software, IRIS Intrepid II, Thermo Electron Corporation, USA). This analysis was carried out in the Soils, Water and Environment Research Institute (SWERI) which belongs to Agricultural Research Center (ARC), Giza, Egypt. Soil mechanical and chemical analyses were carried out according to the modified methods described by Farrag *et al*., (2013, a).

Plant preparations for different chemical analyses

Mature *C. procera* plant samples were collected then washed several times by deionized water to remove extraneous and salts then separated to individual organs of leaves, stems and roots. Plant samples then divided into two categories; the fresh one for the enzyme activity, pigment and hormone analyses, and the other oven dried one at 70 ^oC for chemical ingredients of the studied species.

Chemical ingredients of different plant organs of C. procera

Chemical analysis for the ingredients of *C. procera* leaves, stem and root was selected in the flowering growth stage. Total carbohydrates were determined according to the method of Nelson, (1944) whereas protein content was estimated by Lowry *et al*., (1951). Lipid and fiber were analyzed according to (IUPAC, 1999). This analysis was carried out in the Food and Fodder Research Institute (FFRI) which belongs to Agricultural Research Center (ARC), Giza, Egypt.

Estimation of major and minor elements of C. procera leaves

Exact one gram of *C. procera* leaves (in the flowering growth stage) was digested in 1:2:2 (v:v:v) HNO3: HCl:HClO4 mixture to obtain the total element (metal) content. Concentration of different elements in the leaf samples were

determined in the Cairo University Microanalysis Unit (CUMU), Cairo University, Giza, Egypt. This analysis was determined according to the modified method described by Farrag (2007).

Determination of phenols and proline

Phenols (as %) and proline (as µg/g) contents of *C. procera* leaves in the flowering stage as well as for seedlings in the seedling stage were estimated according to the method of Bourrel *et al.,* (1995). This analysis was carried out in the Soils, Water and Environment Research Institute (SWERI) which belongs to Agricultural Research Center (ARC), Giza, Egypt.

Determination of phytohormones

Two important phytohormones were selected for the determination in fresh *C. procera* leaves in the flowering growth stage as well as for seedlings in the seedling stage; Indole-3-acetic acid (IAA) and Gibberellin (GA_3). Concentration of (IAA) was carried out according to the method described by Czerpak and Bajguz (1997), while (GA_3) was estimated according to Czerpak *et al*., (2006). This analysis was carried out in (SWERI), Giza, Egypt.

Determination of pigments

Exact of 400 mg fresh leaf sample of *C. procera* in the flowering growth stage was used and extracted with aqueous 80% acetone in a mortar with the aid of clean Fontainebleau sand with absorbances A= 470, 520, 647 and 663 nm for Carotene, xanthophylls, chlorophyll a and chlorophyll b; respectively, and recorded on a spectrophotometer (Thermo Spectronic Helios α). Analyses were carried according to Lichtenthaler, (1987) and the results were expressed as chlorophylls and xanthophylls content in the tissue (µg g-1 FW). This analysis was carried out in (SWERI), Giza, Egypt.

Determination of some enzyme activities

All enzyme activity data were related to *C. procera* leaves fresh weight (FW) in the flowering growth stage. About 1g of leaf sample was ground in an ice-cooled mortar with 5ml of ice-cooled 50 mM Na-phosphate buffer (pH 7.8, containing 0.1 mM EDTA) and polyvinyl polypyrrolidone (PVPP). The homogenate was centrifuged at 10.000 rpm for 10 min. at 4 ^{o}C and the supernatant used for enzyme activity determinations. Amylase activity was determined using a method described by Cao *et al*., (2004) and modified method described by Afifi *et al.,* (1996), whereas the estimation of protease enzyme was made according to the method of Ong and Gaucher, (1973). Peroxidase activities were determined according to modified method described by Invenish *et al*., (1995). All enzyme activities of the current work were expressed as mg/g FW. This analysis was carried out in (SWERI), Giza, Egypt.

Analysis of data

Data were analyzed using Statistical Package for the Social Sciences (SPSS ver.14). Means were separated using Duncan's multiple range test at a P value of 0.05.

Results

Vegetative attributes

Root, shoot lengths and R/S ratio

The effect of magnetic water treatment on the root and shoot lengths of *C. procera* demonstrated stimulating effects on both root and shoot lengths as compared to control plants treated by nonmagnetic irrigation water throughout the different growth stages. This Stimulating effect was clear in the seedling and flowering growth stages. In case of *C. procera* treated with nonmagnetic and magnetic water during the seedling growth stage, the recorded root lengths were 3.62, 4.13, 4.56 and 9.31cm ($p< 0.05$) for the treatments of control, T_1, T_2 and T_3; respectively, compared to the higher values of 11.25, 16.05, 25.46 and 23.47cm recorded the flowering growth stage (Fig. 1, A). In addition, magnetic water stimulated the root growth in T_3 samples to about its double and sometimes triple value as compared to control samples.

Shoot lengths of the treated *C. procera* on the other hand, followed the same stimulating trend as root depths; the shoot height of *C. procera* plants treated with nonmagnetic water at the mature growth stage was 29.36 cm for control samples and this value was significantly ($p< 0.01$) increased to 50.45, 70.56 and 72.46 cm in the treated shoots by magnetic water of T_1, T_2 and T_3; respectively (Fig. 1, B).

The root-shoot (R:S) ratio for all treated *C. procera* plants either by magnetic or nonmagnetic water plants, nearly in all growth stages except seedling stage, was almost lower than unity. As an example the estimated R:S ratios for *C. procera* during the mature growth stage were 0.17, 0.26, 0.28 and 0.29 in control, T1, T2 and T3 plants; respectively, while the same treatments recorded (R:S) ratios amounting to 1.67, 1.44, 1.01 and 1.98 in the seedling growth stage (Fig. 2).

Fresh weights of C. procera organs

The presented data in Table 1 showed significant increase in the recorded fresh weight values of different plant organs treated by magnetic water as compared to those of untreated one.

Considering *C. procera* in the seedling growth stage, the recorded fresh weights for leaves, stem and root were 0.014, 0.065, 0.007 g; respectively, for plants irrigated with nonmagnetic water (control), and these values increased in the subsequent treatments recording maximum values amounting to 0.117, 0.124 and 0.033 g for the same organs of treatment (T_3) during the same growth stage.

Considering the flowering growth stage of *C. procera*, fresh weight of leaves recorded 5.713 gm in leaves of control samples and this value significantly ($p<0.05$) increased to 11.01 g in treatment (T_3). Stem, root and flowers recorded 18.844, 9.372 and 0.667 g; respectively, and these values significantly increased to about its five times.

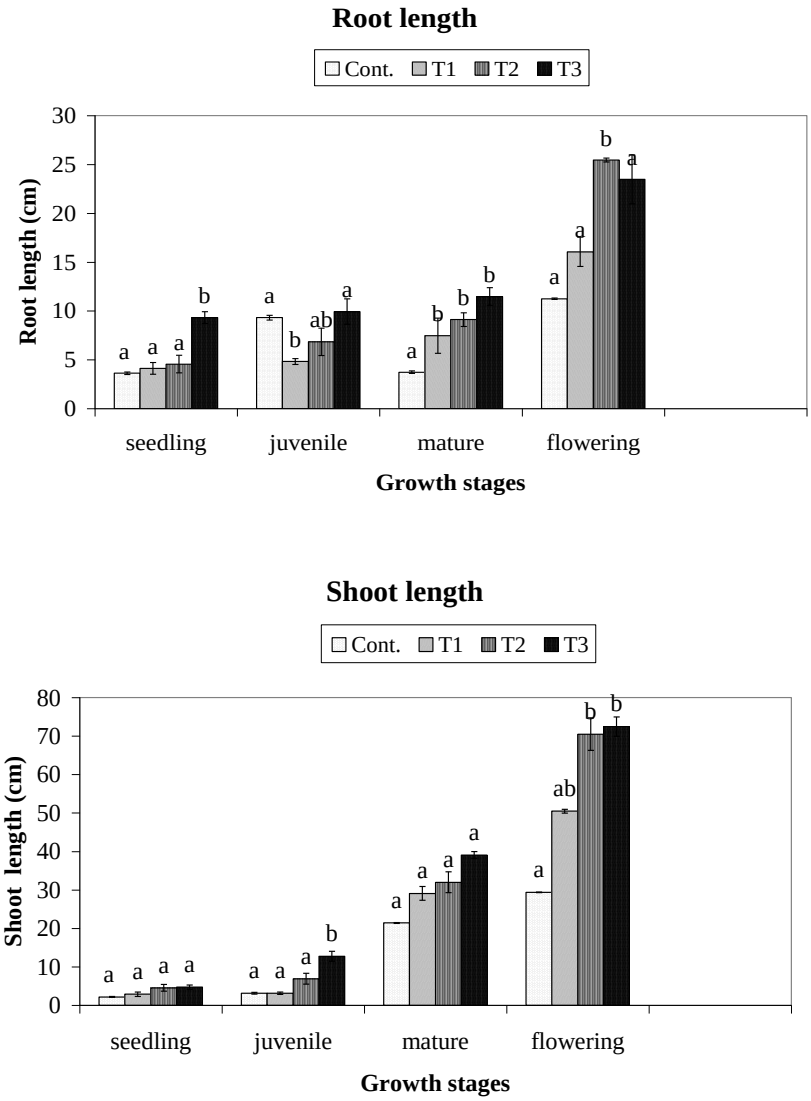

Fig. 1. Mean root length (A) and mean shoot length (B) of *C. procera* growing under different magnetic water treatments (C= irrigation with 300 ml nonmagnetic water, T1= irrigation with 200ml nonmagnetic water+100ml magnetic water, T2= irrigation with 100ml nonmagnetic water+200ml magnetic water and T3= irrigation with 300ml magnetic water) at different growth stages; (seedling) = after 21 days from sowing, (Juvenile) = 45 days, (mature) = 90 days and (flowering) = 180 days. Vertical bar around the mean is the standard deviation.

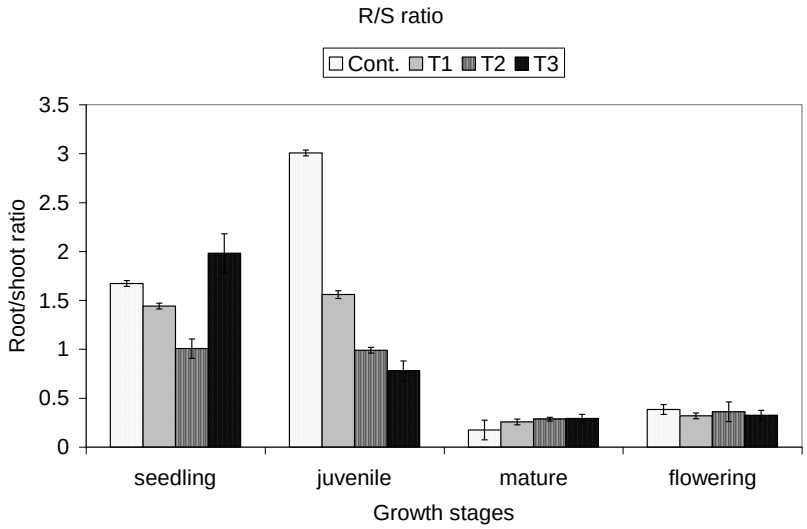

Fig. 2. Mean root/shoot ratio of *C. procera* growing under different magnetic water treatments (Cont. = irrigation with 300ml nonmagnetic water, T_1= irrigation with 200ml nonmagnetic water+100ml magnetic water, T_2= irrigation with 100ml nonmagnetic water+200ml magnetic water and T_3= irrigation with 300ml magnetic water) at different growth stages; (seedling) = after 21 days, (Juvenile) = 45 days, (mature) = 90 days and (flowering) = 180 days. Vertical bar around the mean is the standard deviation.

In plants irrigated by maximum values of magnetic water (T_3) and recorded values amounting to 88.525, 54.46 and 12.667 in the same organs.

Comparing different plant organs of the test species presented in Table 1, it is clear that maximum fresh weight values towards the stem organ especially in the late growth stages (mature and seedling), followed by root, and leaves then finally flowers.

Dry matter allocation to the different plant organs

Allocation of dry matter among different plant organs in the test species was illustrated in Fig. 3 and the data given in App. Table 1.

Considering *C. procera* plants irrigated with either magnetic or nonmagnetic water during the juvenile growth stage, the allocation to leaves was the highest among the other plant organs recording maximum values amounting to 51.41, 62.74, 63.64 and 33.12% for control, T_1, T_2 and T_3 plant samples; respectively. Oppositely, dry matter allocation of *C. procera* leaves attained the lowest values during the flowering growth stage recording 13.44, 3.98, 4.57 and 3.06% for the same treatments.

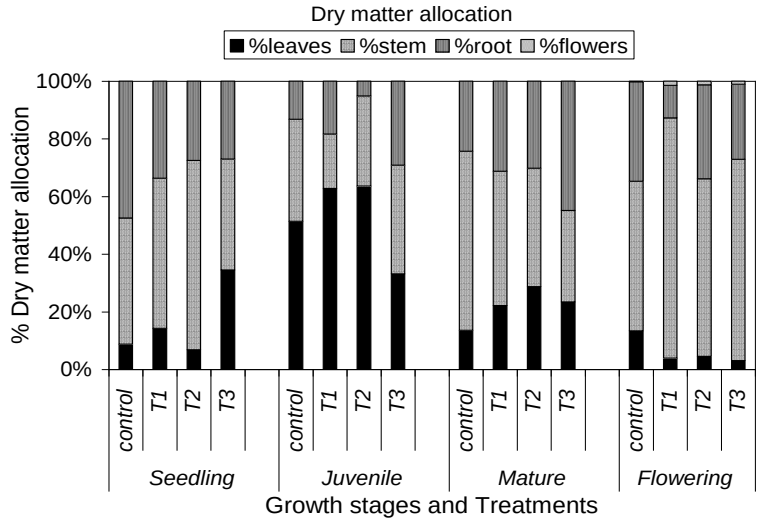

Fig. 3. Percent dry matter allocation of different *C. procera* plant organs, growing under different magnetic water treatments; (Control= irrigation with 300ml nonmagnetic water, T_1= irrigation with 200ml nonmagnetic water+100ml magnetic water, T_2= irrigation with 100ml nonmagnetic water+200ml magnetic water and T_3= irrigation with 300ml magnetic water) at different growth stages; (seedling) = after 21 days, (Juvenile) = 45 days, (mature) = 90 days and (flowering) = 180 days.

Comparing the dry matter allocation of plant organs of the control with that irrigated with magnetic water it can easily deduced that there was general increase in the dry matter of irrigated plants with magnetic water as compared to those irrigated by nonmagnetic water. For instance, dry matter allocation of *C. procera* samples treated with nonmagnetic water during the mature growth stage recorded 13.59, 62.13 and 24.26% in leaves, stem and root organs; respectively, while these values generally increased to 22.13, 46.6 and 31.38% in plants irrigated by magnetic water (T_1) in the same growth stage.

The given data in App. Table 1 revealed that, dry matter allocation for flowers recorded minimum values amounting to 0.21, 1.41, 1.29 and 1.04% in control, T1, T2 and T3 in *C. procera* plants; respectively.

Comparing dry matter allocation of the different plant organs in most growth stages demonstrated that, percent allocation of stem > leaves > root > flowers.

In general, irrigation of the test species by magnetic water, significantly affects the dry matter allocation to the different plant organs especially leaves and stem and this effect increases and clearly detected at the late growth stages (mature and flowering) than the early growth stages (seedling and juvenile).

TABLE 1. Mean and standard deviations of fresh weight (gm) of different plant organs of C. procera growing under different magnetic water treatments (C= irrigation with 300ml nonmagnetic water, T1= irrigation with 200ml nonmagnetic water+100ml magnetic water, T2= irrigation with 100ml nonmagnetic water+200ml magnetic water and T3= irrigation with 300ml magnetic water) in different growth stages; (seedling) = after 21 days, (Juvenile) = 45 days, (mature) = 90 days and (flowering) = 180 days. *P<0.05, **P<0.01, n.s. = non significant.

Growth stage† & treatment		Growth parameter			
		f.wt. leaves	f.wt. stem	f.wt. root	f.wt. flowers
Seedling	C	0.014±0.003a	0.065±0.003a	0.007±0.0002a	------
	T1	0.055±0.007a	0.090±0.001a	0.009±0.0007a	------
	T2	0.073±0.003a	0.166±0.091a	0.030±0.0072b	------
	T3	0.117±0.027a	0.124±0.007a	0.033±0.0028b	------
		n.s.	n.s.	*	------
Juvenile	C	0.115±0.032a	0.086±0.001a	0.074±0.0001a	------
	T1	0.237±0.019a	0.101±0.008b	0.073±0.0083a	------
	T2	0.319±0.024a	0.185±0.034b	0.096±0.0037a	------
	T3	0.757±0.051a	0.539±0.004b	0.393±0.0024b	------
		n.s.	**	*	------
Mature	C	2.073±0.357a	8.681±0.215a	5.031±0.684a	------
	T1	3.053±0.930a	9.667±0.279a	5.566±0.054a	------
	T2	3.613±0.052a	10.386±0.967a	6.813±0.328a	------
	T3	5.702±0.854a	20.266±2.105b	16.907±1.254a	------
		n.s.	*	n.s.	------
Flowering	C	5.713±0.961a	18.844±1.027a	9.372±0.769a	0.667±0.0025a
	T1	6.783±0.729a	58.979±4.259b	6.055±0.086a	9.333±0.247a
	T2	10.196±1.068b	76.375±11.027b	43.265±2.035ab	11.363±1.035a
	T3	11.010±1.244b	88.525±6.667b	54.460±7.054b	12.667±1.025a
		*	*	**	n.s.

Water content of different plant organs

Water content in different plant organs of the test species throughout different growth stages was studied and the data was illustrated in Fig. 4.

Comparing values of water contents of different plants showed general increase in the following order: leaves> flowers> stem> root. For example, the estimated water contents of *C. procera* organs irrigated with magnetic water (T_1) during the flowering growth stage were 80.44, 70.27, 52.94 and 37.73% in leaves, flowers, stem and root; respectively.

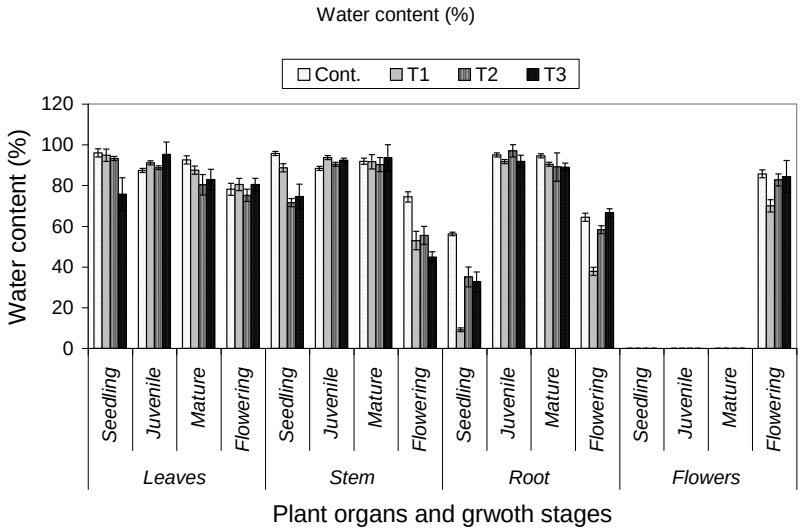

Fig. 4. Mean water content of different *C. procera* plant organs, growing under different magnetic water treatments; (Cont. = irrigation with 300ml nonmagnetic water, T_1= irrigation with 200ml nonmagnetic water+100ml magnetic water, T_2= irrigation with 100ml nonmagnetic water+200ml magnetic water and T_3= irrigation with 300ml magnetic water) at different growth stages; (seedling) = after 21 days, (Juvenile) = 45 days, (mature) = 90 days and (flowering) = 180 days. Vertical bar around the mean is the standard deviation.

The illustrated data in Fig. 4, demonstrated that the water contents of different plant organs of the test species recorded relatively higher values in the first three growth stages; namely, seedling, juvenile and mature growth stages as compared to late growth stage; flowering in each plant organ. Water contents were 93.27, 88.74 and 80.35% for *C. procera* leaves irrigated with (T_2) during the seedling, juvenile and flowering growth stages; respectively, and these values were reduced into only 75.15% in the flowering growth stage.

Number of leaves and leaf area

The current study revealed stimulating effect of irrigation with magnetic water on the number of leaves and leaf area of *C. procera* plants as compared to those irrigated with normal nonmagnetic water and the data was illustrated in Fig. 5.

Number of leaves

The illustrated data in Fig. 5, showed general increase in the number of leaves in the magnetic water irrigated samples in the different growth stages as compared to that of nonmagnetic water and this increament proceeds and recorded its maximum as the plant ages. Number of *C. procera* leaves in the

seedling growth stage ranged between 2.1 in control samples and increased to its double (4.2) when the test species was irrigated with the pure magnetic water (T_3). Furthermore, number of leaves in the flowering growth stage recorded 14.66, 22.34, 28.37 and 29.98 in *C. procera* plants referred control, T_1, T_2 and T_3; respectively.

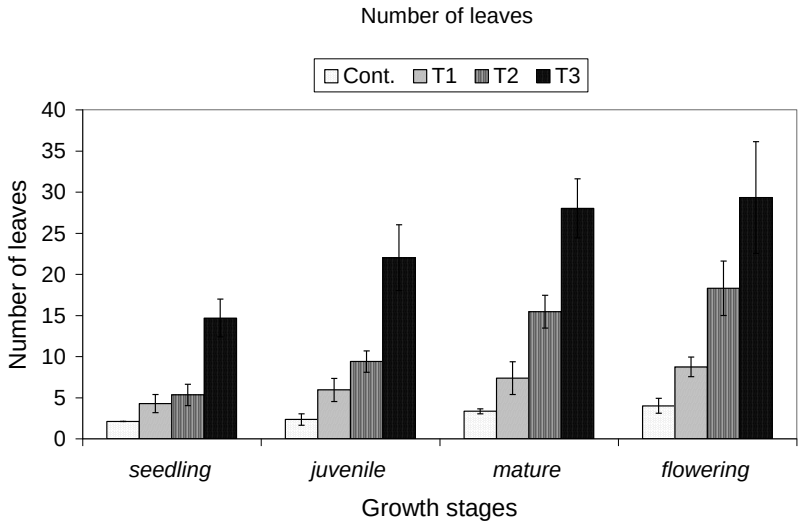

Fig. 5. Mean number of *C. procera* leaves growing under different magnetic water treatments (Cont. = irrigation with 300ml nonmagnetic water, T_1= irrigation with 200ml nonmagnetic water+100ml magnetic water, T_2= irrigation with 100ml nonmagnetic water+200ml magnetic water and T_3= irrigation with 300ml magnetic water) at different growth stages; (seedling) = after 21 days, (Juvenile) = 45 days, (mature) = 90 days and (flowering) = 180 days. Vertical bar around the mean is the standard deviation.

Leaf area

The recorded leaf area of *C. procera* plants irrigated with magnetic water similar way to the above mentioned trend considering number of leaves and the data illustrated in Fig. 6. Maximum leaf area values of *C. procera* leaves were obtained on irrigation by pure magnetic water and amounting to 9850.6, 12825.7 and 15990.3 mm^2 during the juvenile, mature and flowering growth stages; successively. The leaf area was only 6981.35 mm^2 in case of leaves irrigated with magnetic water in the seedling stage.

Growth analysis and its parameters

Growth analysis of the test species and the variation in growth parameters in response to the effect of magnetic water irrigation on the growth of *C. procera*, including relative growth rate (RGR), net assimilation rate (NAR) and leaf area ratio (LAR) of the test species are illustrated in Fig. (7-9) and the data given in App. Tables (2).

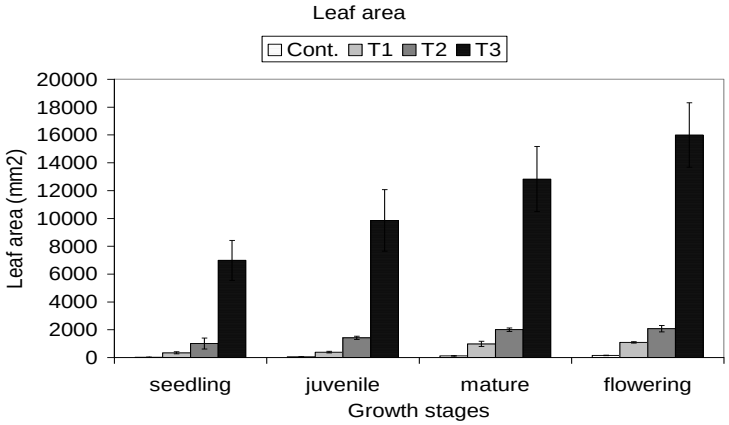

Fig. 6. Mean leaf area of *C. procera* leaves growing under different magnetic water treatments (Cont. = irrigation with 300ml nonmagnetic water, T_1= irrigation with 200ml nonmagnetic water+100ml magnetic water, T_2= irrigation with 100ml nonmagnetic water+200ml magnetic water and T_3= irrigation with 300ml magnetic water) at different growth stages; (seedling) = after 21 days, (Juvenile) = 45 days, (mature) = 90 days and (flowering) = 180 days. Vertical bar around the mean is the standard deviation.

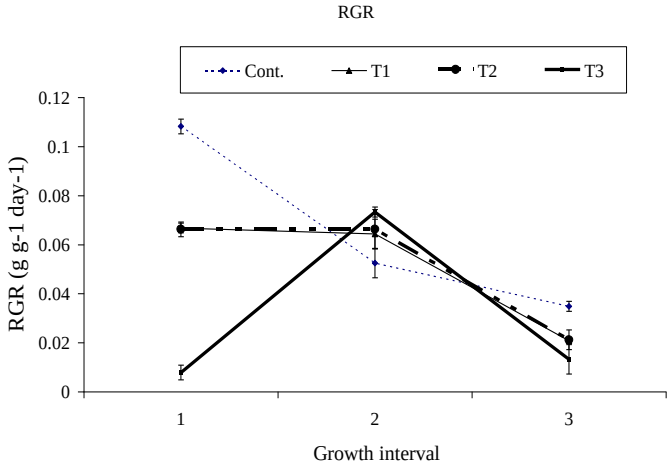

Fig. 7. Relative growth rate (RGR) of different *C. procera* growth stages (1= seedling-juvenile stage, 2= juvenile- mature stage, 3= mature- flowering stage), growing under different magnetic water treatments; (Cont. = irrigation with 300ml nonmagnetic water, T_1= irrigation with 200ml nonmagnetic water+100ml magnetic water, T_2= irrigation with 100ml nonmagnetic water+200ml magnetic water and T_3= irrigation with 300ml magnetic water). Vertical bar around the mean is the standard deviation.

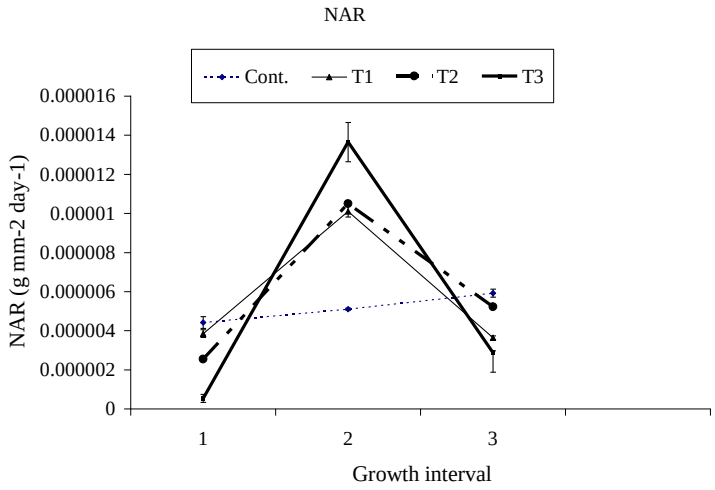

Fig. 8. Net assimilation rate (NAR) of different *C. procera* growth stages (1= seedling-juvenile stage, 2= juvenile- mature stage, 3= mature- flowering stage), growing under different magnetic water treatments; (Cont. = irrigation with 300ml nonmagnetic water, T_1= irrigation with 200ml nonmagnetic water+100ml magnetic water, T_2= irrigation with 100ml nonmagnetic water+200ml magnetic water and T_3= irrigation with 300ml magnetic water). Vertical bar around the mean is the standard deviation.

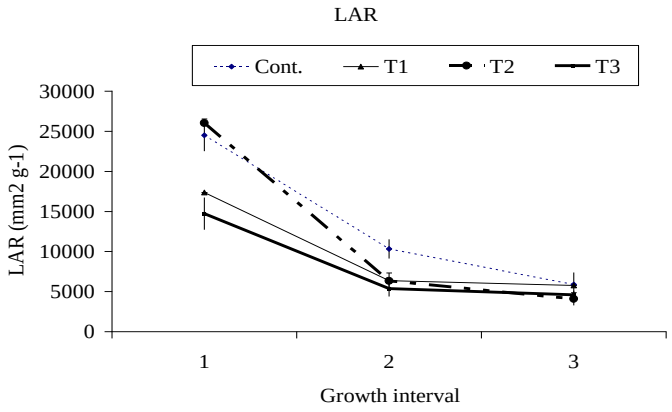

Fig. 9. Leaf area ratio (LAR) of different *C. procera* growth stages (1= seedling-juvenile stage, 2= juvenile- mature stage, 3= mature- flowering stage), growing under different magnetic water treatments; (Cont. = irrigation with 300ml nonmagnetic water, T_1= irrigation with 200ml nonmagnetic water+100ml magnetic water, T_2= irrigation with 100ml nonmagnetic water+200ml magnetic water and T_3= irrigation with 300ml magnetic water). Vertical bar around the mean is the standard deviation.

Relative Growth Rate (RGR)

The RGRs of the test species generally decreased with time. The recorded RGRs values of *C. procera* in the second growth interval (juvenile- mature) were 0.0525, 0.0643, 0.0662 and 0.0732 g g^{-1} day^{-1} for the control, T_1, T_2 and T_3 samples; respectively. These values greatly and significantly ($p< 0.05$) reduced in the third growth interval (mature- flowering) into 0.0348, 0.0208. 0.0212 and 0.0131 g g^{-1} day^{-1} for the same treatments; respectively (Figure 7 and App. Table 2).

The RGRs of *C. procera* control plants is generally higher than that of irrigated *C. procera* plants by magnetic water especially in case of the first and third growth intervals. For example the RGR of *C.procera* control plants during the first growth interval (seedling– juvenile) was 0.1082 g g^{-1} day^{-1} and this value significantly ($p< 0.05$) reduced into (0.0667, 0.0662 and 0.0078 g g^{-1} day^{-1} in plants of treatments T_1, T_2, and T_3; respectively.

On the contrary, the RGRs of *C. procera* treated by magnetic water took a reversed trend than the above mentioned case in most growth stages.

Net Assimilation Rate (NAR)

The variation of NAR values for the studied species in the present investigation depended on both the amount of magnetic water and the growth interval. Net assimilation rate of different *C. procera* growth intervals irrigated by both normal (nonmagnetic) and magnetic water was illustrated in Figure 8 and the data was given in App. Table 2. The second growth interval (juvenile-mature) gave the maximum NARs as compared to the other growth intervals recording values of $5.1x10^{-6}$,$1.01\ x10^{-5}$, $1.05\ x10^{-5}$ and $1.36x\ x10^{-5}$ in *C. procera* of the control, T_1, T_2 and T_3 treatments; respectively.

Leaf Area Ratio (LAR)

The highest LAR values were recorded in the first growth interval (seedling-juvenile), then the values decreased in the subsequent growth intervals recording their minimum values in the third growth interval (mature- flowering stage) as illustrated in Figure 9 and tabulated in App. Table 2.

Values of LAR for *C. procera* plants recorded its maximum during the seedling- juvenile growth interval and amounted to 24498.29, 17360.72, 26016.88 and 14710.35 mm^2 g^{-1} for the control, T_1, T_2 and T_3 treated plants, respectively.

It is to be mentioned that nearly throughout the whole growth intervals, higher LAR values were attained in *C. procera* plants irrigated by normal nonmagnetic water as compared with those of plants irrigated with magnetic water. For example, LAR of *C. procera* significantly ($p< 0.01$) recorded 10300.65, 6368.59, 6313.257 and 5369.629 mm^2 g^{-1} for control, T_1, T_2 and T_3 plants; respectively during the juvenile- mature growth interval.

TABLE 2. Selected chemical and metal content (in three sequential samples) of the investigated nonmagnetic (a) and magnetic (b) water samples. (Mean values are given ±SD).

Variable	Type of irrigated water	
	Nonmagnetic water (a)	Magnetic water (b)
Total dissolved salts		
EC as dS/m	0.2[a] ±0.012	0.38[a]±0.07
EC as ppm	124.5 [a] ±3.39	243.2[b]±35.6
pH value	7.5 [a] ±0.67	7.3[a]±0.29
dissolved anions (mg kg-1 D.W)		
Cl^-	1.74 [a] ±0.050	3.01[b]±0.07
SO_4^{--}	0.2 2[a] ±0.008	0.43[a]±0.06
Soluble CO_3^{--}	0.00 [a] ±0.000	0.00 [a] ±0.00
HCO_3^-	0.16 [a] ±0.006	0.19[a]±0.006
Dissolved cations (mg kg-1 D.W)		
Potasium	0.10 [a] ±0.003	0.11[a] ±0.036
Calcium	0.35 [a] ±0.040	0.41 [a] ±0.01
Magnesium	0.21[a]±0.050	0.33 [b] ±0.02
Sodium	1.43 [a] ±0.08	2.79 [b]±0.08
Elements (mg kg-1 D.W.)		
NH_4^+	1.26[1 a] ±0.024	0.63 [b] ±0.006
NO_3^-	5.985 [b] ±0.280	11.34 [a]±0.35
P	0.00[0 a] ±0.000	0.00 [a] ±0.00
Fe	0.011 [b] ±0.002	0.013 [a] ±0.003
Mn	0.001 [a] ±0.0003	0.019 [b] ±0.006
Zn	0.000 [a] ±0.000	0.007 [b]±0.0003
Cu	0.201 [b] ±0.005	0.012 [a] ±0.002
B	0.094 [a] ±0.001	0.231 [b] ±0.006

Water and soil analyses

Analyses of water (normal nonmagnetic and magnetic one) as well as the soil used in the greenhouse experiment were carried out to evaluate the effect of

magnetic field on the chemical and physical characters especially in water. The estimated values are presented in Tables 2 and 3.

Water analysis

The presented data in Table 2 showed comparative differentiation between the chemical analyses of nonmagnetic and magnetic water. Electric conductivity (EC) of magnetic water recorded 0.38 dS/m, while reduced to about its half value (0.2 dS/m) in the case of nonmagnetic water. Dissolved anions of chlorides recorded the maximum values among the other dissolved ions (1.74 and 3.03 mg kg^{-1} D.W.) in nonmagnetic and magnetic waters; respectively. Sodium recorded the maximum values among different dissolved cations recording 1.43 and 2.79 mg kg^{-1} D.W. in nonmagnetic and magnetic waters; respectively. Nitrates recorded higher value (11.34 mg kg^{-1} D.W.) in magnetic water than for the nonmagnetic water (5.985 mg kg^{-1} D.W.). Water pH varied from 7.3 in the magnetic water samples to 7.5 in the nonmagnetic water sample. The differences in the metal concentrations among the different water samples recorded more values in the case of magnetic water than those of nonmagnetic one. Concentration of elements in the different water samples followed the order: Cu> B>Fe>Mn>Zn>P.

Soil analysis

The presented data in Table 3 showed some chemical and mechanical analyses of the used soil. Electric conductivity (EC) recorded 9.89 dS/m (1205.6 ppm). Among the different dissolved ions, chlorides recorded the maximum value of 90.52 mg kg^{-1} D.W., this was followed by bicarbonates (5.2 mg kg^{-1} D.W.) with the absence of soluble carbonate in the soil. Sodium attained the maximum value of (37.9 mg kg^{-1} D.W.) among the different dissolved cations, followed by calcium then magnesium and finally potassium. Ammonia recorded high value (21.44 mg k^{g-1} D.W.) in the estimated soil sample.

The data in (Table 3) revealed that the soil is slightly alkaline in reaction recording a pH value of 8.04. Thirteen elements were analyzed in the soil of the current work. Lead recorded the maximum metal concentration amounting to 69.7 (mg k^{g-1} D.W.) while cobalt attained the minimum value of 0.08. According to the metal concentrations in the soil, one can arrange them in the order: Pd> Ni>Fe>Cd>Zn>P>Cu>Mn>As>B>Mo>Cr>Co. The soil mechanical analysis revealed that the soil texture is sandy clay with 60.3% porosity and the coarse sand (59.5%) is the prominent soil variable particles.

Chemical analyses of C. procera

Numerous chemical analyses were carried out in the current work as an attempt to evaluate the effect of using magnetic water on the chemical constitutions and some physiological aspects of the studied species such as: plant pigments, some enzyme activities and phytohormones.

TABLE 3. Selected chemical and mechanical analyses (in three sequential samples) of the investigated soil sample. (Mean values are given ±SD).

Soil variable	Investigated soil sample (Mean ±SD)
Total dissolved salts	
EC as dS/m	9.89 ±0.67
EC as ppm	1205.6±56.92
pH value	8.04 ±0.083
dissolved anions (mg kg-1 D.W)	
Cl^-	90.52 ±8.05
SO_4^{--}	2.42 ±0.13
Soluble CO_3^{--}	0.00 ±0.00
HCO_3^-	5.20 ±0.21
Dissolved cations (mg kg-1 D.W)	
Potasium	1.02 ±0.005
Calcium	31.21 ±2.61
Magnesium	28.11 ±1.82
Sodium	37.90 ±3.79
Elements (mg kg-1 D.W.)	
NH_4^+	21.44 ±2.12
NO_3^-	6.12 ±0.65
P	4.86 ±0.12
Fe	23.41 ±1.83
Mn	2.45 ±0.65
Zn	6.23 ±0.69
Cu	3.34 ±0.12
B	1.07 ±0.05
Mo	0.95 ±0.03
Cd	15.33 ±1.12
Co	0.08 ±0.002
Cr	0.52 ±0.001
Ni	41.5±1.67
Pd	69.7 ±6.83
As	1.83 ±0.03
Organic matter	3.2%
Soil mechanical analysis	
Coarse sand (%)	59.5 ±2.72
Fine sand (%)	11.5 ±0.79
Silt (%)	15.7 ±0.09
Clay (%)	13.3 ±0.63
Porosity (%)	60.3 ±2.08
Soil texture	Sandy clay

Chemical ingredients of different C. procera organs

The data in Table 4, demonstrated the effect of magnetic water on chemical ingredients of the studied species. Comparing the recorded values of these ingredients revealed that total carbohydrates achieved the highest value while lipid recorded the minimum values. The estimated chemical ingredients of *C. procera* leaves irrigated by magnetic water (T_1) were 40.56, 14.25, 0.63, 12.89 and 8.41% for total carbohydrates, fiber, protein, lipid, ash and moisture contents; respectively. In addition, comparing the obtained data in case of using magnetic and nonmagnetic water, one can easily observe that irrigation of the test species by magnetic water increased the values of chemical ingredients in the total carbohydrates, fiber, protein and lipid content. On the contrary, irrigation of the test species by magnetic water generally decreased the ash and moisture contents when compared with those samples irrigated with nonmagnetic water. For instance, the protein content of leaves in control samples recorded 17.61% which was significantly ($p< 0.01$) increased to 23.26, 18.21 and 23.68% in samples irrigated by magnetic water treatments (T_1, T_2 and T_3); respectively. Moreover, the total carbohydrate content recorded maximum values in leaves while the root contained maximum values of proteins. Magnetic water irrigation increase the moisture contents in most cases in the different plant organs.

TABLE 4. Quantitative determination of the chemical ingredients (%) of different *C. procera* plant organs growing under different magnetic water treatments; (Control = irrigation with 300ml nonmagnetic water, T_1= irrigation with 200ml nonmagnetic water+100ml magnetic water, T_2= irrigation with 100ml nonmagnetic water+200ml magnetic water and T_3= irrigation with 300ml magnetic water) in the flowering growth stage.

Plant organ	Treatment	Chemical ingredients (%)					
		Total carbohydrates	Fiber	Protein	Lipid	Ash	Moisture
Leaves	Control	39.86^{a}	12.66^{a}	17.61^{a}	0.37^{a}	18.23^{b}	11.27^{b}
	T_1	40.56^{a}	14.25^{a}	23.26^{b}	0.63^{b}	12.89^{a}	8.41^{a}
	T_2	41.89^{a}	12.55^{a}	18.21^{ab}	0.42^{b}	14.25^{a}	12.68^{b}
	T_3	42.58^{a}	14.29^{a}	23.68^{b}	0.57^{b}	10.03^{a}	9.85^{a}
		n.s.	n.s.	**	*	*	*
Stem	Control	35.38^{a}	12.08^{a}	15.30^{a}	0.12^{a}	19.91^{a}	17.21^{a}
	T_1	32.04^{b}	11.24^{a}	17.58^{a}	0.38^{b}	20.05^{a}	18.71^{a}
	T_2	38.41^{a}	13.40^{b}	17.60^{a}	0.28^{b}	16.81^{a}	13.50^{a}
	T_3	39.56^{a}	13.29^{b}	19.40^{a}	0.30^{b}	12.65^{b}	14.80^{a}
		*	*	n.s.	*	*	n.s.
Root	Control	22.52^{a}	19.42^{a}	25.41^{a}	0.76^{a}	15.77^{a}	16.12^{a}
	T_1	34.59^{b}	12.03^{a}	20.12^{b}	0.32^{b}	20.61^{a}	12.33^{b}
	T_2	29.09^{ab}	15.37^{a}	16.40^{b}	0.32^{b}	20.91^{a}	17.91^{a}
	T_3	35.75^{b}	13.82^{a}	20.07^{b}	0.59^{a}	15.87^{a}	13.90^{a}
		**	n.s.	*	*	n.s.	*

Concentration of major and minor elements in C. procera leaves

Effect of irrigation with magnetic water on some metal and element contents of the test species was studied and the data given in Table 5. Manganese (Mn) recorded maximum values of 105.69, 110.98, 117.49 and 250.2 mg/kg in the control, T_1, T_2 and T_3 *C. procera* samples; respectively. On the other hand, iron (Fe) attained minimum values of 0.14, 0.13, 0.04 and 0.03 % for plant samples of the same previous order. Comparing the recorded values of elements and metals in the *C. procera* leaves, we can arrange these items according to their concentration as follows:

Mn> B> Zn> Cu> N> Ca> Mg> K> P> Fe. In most cases, magnetic water increase the element and metal contents of leaves as compared to those of nonmagnetic ones except for iron and calcium.

TABLE 5. Concentration of major and minor elements in *C. procera* leaves growing under different magnetic water treatments; (C= irrigation with 300ml nonmagnetic water, T_1= irrigation with 200ml nonmagnetic water+100ml magnetic water, T_2= irrigation with 100ml nonmagnetic water+200ml magnetic water and T_3= irrigation with 300ml magnetic water) in the flowering growth stage.

Treatment	(%)						mg/kg			
	N	P	K	Fe	Ca	Mg	Mn	Zn	Cu	B
C	1.74^{a}	0.11^{a}	0.52^{a}	0.14^{a}	7.01^{a}	0.62^{a}	105.69^{a}	9.33^{a}	17.00^{a}	99.32^{a}
T_1	1.65^{a}	0.25^{b}	0.53^{a}	0.13^{a}	3.94^{b}	0.25^{a}	110.98^{a}	33.42^{a}	45.98^{b}	5.84^{b}
T_2	2.00^{a}	0.15^{a}	0.97^{b}	0.04^{b}	0.63^{c}	0.48^{a}	117.49^{a}	70.08^{a}	13.93^{a}	69.86^{a}
T_3	2.17^{a}	0.17^{a}	0.73^{ab}	0.03^{a}	0.82^{c}	1.02^{a}	250.20^{b}	115.74^{b}	24.92^{ab}	148.82^{c}
	n.s.	*	**	*	**	n.s.	*	*	**	**

Concentration of phenol, proline and phytohormones in C. procera leaves

The given data in Table 6, revealed that phenol content was significantly ($p< 0.05$) increased from 9% in control samples of *C. procera* leaves to 11.5% in samples of T_3. The magnetic water increased the proline content from 3463 (µg/g) recorded in control *C. procera* leaves to 3588, 3673 and 3832 (µg/g) for treatments T_1, T_2 and T_3; respectively. Magnetic water stimulated the production of phytohormones as compared to the nonmagnetic water. For example, gibberellins (GA_3) production was 363 (µg/g) in leaves irrigated with nonmagnetic water (control) which significantly ($p<0.05$) increased to 421, 457 and 497 in the case of magnetic water treatments T_1, T_2 and T_3; respectively (Table 6). Similarly, indole acetic acid (IAA) follow the same trend.

TABLE 6. Concentration of phenol, proline, gibberellins (GA_3) and indole acetic acid (IAA) in *C. procera* leaves growing under different magnetic water treatments; (Control = irrigation with 300ml nonmagnetic water, T_1= irrigation with 200ml nonmagnetic water+100ml magnetic water, T_2= irrigation with 100ml nonmagnetic water+200ml magnetic water and T_3= irrigation with 300ml magnetic water) in the flowering growth stage.

Treatment	Concentration of ….			
	Phenol (%)	Proline (µg/g)	GA_3 (µg/g)	IAA (µg/g)
Control	9.0[a]	3463[a]	363[a]	37.2[a]
T_1	10.5[b]	3588[a]	421[b]	42.5[a]
T_2	8.0[a]	3673[a]	457[b]	56.8[b]
T_3	11.5[b]	3832[b]	497[b]	59.1[b]
	*	*	*	*

Plant pigments of C. procera leaves

The presented data in Table 7, estimated the plant pigments in leaves of *C. procera* during the flowering growth stage. Data clarified that magnetic water stimulates the production of chlorophyll a and b, while it inhibits the production of carotene and xanthophylls. For xample, chlorophyll a significantly ($p<0.05$) increased from 101.63 (µg/g) in control *C. procera* leaves to 102.51, 105.59 and 117.68 (µg/g) in leaves irrigated with magnetic water of T_1, T_2 and T_3; respectively. Meanwhile, carotene and xanthophylls recorded 36.63 (µg/g) and this value decreased into 35.89, 35.01 and 35.12 (µg/g) in leaves irrigated with magnetic water of T_1, T_2 and T_3; respectively. Chlorophyll a recorded higher values in *C. procera* leaves than that of chlorophyll b. Moreover, chlorophyll b was more affected by the irrigation with magnetic water than chlorophyll a.

TABLE 7. Concentration of plant pigments in *C. procera* leaves growing under different magnetic water treatments; (Control = irrigation with 300ml nonmagnetic water, T_1= irrigation with 200ml nonmagnetic water+100ml magnetic water, T_2= irrigation with 100ml nonmagnetic water+200ml magnetic water and T_3= irrigation with 300ml magnetic water) in the flowering growth stage.

Treatment	Type of plant pigment			
	Chlorophylls (µg/g)			Carotene and xanthophyll
	a	b	total	(µg/g)
Control	101.63[a]	17.24[b]	118.87[a]	36.63[a]
T_1	102.51[a]	10.74[a]	113.25[b]	35.89[a]
T_2	105.59[a]	19.86[b]	125.81[ab]	35.01[a]
T_3	117.68[b]	22.43[b]	140.11[b]	35.12[a]
	*	*	**	n.s.

Some enzyme activities of C. procera leaves

Concentration of some important enzyme activities in *C. procera* leaves collected during the flowering growth stage and growing under both magnetic and nonmagnetic water was carried out (Table 8). The data revealed that magnetic water increase the enzyme activity of amylase and decrease the enzyme activities of protease and Peroxidase. For the control case, the recorded enzyme activity of

amylase was 3.22 (mg/g), the value gradually increased on treatment with magnetic water recording its maximum value (6.25 mg/g) in leaves irrigated with T_3 magnetic water. On the contrary, Peroxidase activity decreased from 4.72 (mg/g) in control samples to about its half (2.86mg/g) in leaves irrigated with T_3 magnetic water. Comparing values of different enzyme activities revealed that the maximum enzyme activities were monitored by amylase followed by peroxidase and finally by protease.

TABLE 8. Mean and standard deviations of amylase, protease and Peroxidase (mg/g) activities of *C. procera* leaves growing under different magnetic water treatments (Control = irrigation with 300ml nonmagnetic water, T_1= irrigation with 200ml nonmagnetic water+100ml magnetic water, T_2= irrigation with 100ml nonmagnetic water+200ml magnetic water and T_3= irrigation with 300ml magnetic water) in the flowering growth stage (flowering) = 150 days. *P<0.05, **P<0.01, n.s. = non significant.

Treatment	Type of enzyme		
	Amylase	Protease	Peroxidase
Control	3.22±0.72^{b}	1.78±0.27^{a}	4.72±0.19^{a}
T1	4.22±0.56^{a}	1.04±0.06^{a}	4.02±0.05^{a}
T2	3.91±0.16^{ab}	0.73±0.02^{a}	3.94±0.18^{a}
T3	6.25±0.93^{a}	0.56±0.01^{a}	2.89±0.06^{a}
	**	*	n.s.

App. TABLE 1. Mean and standard deviations of percent dry matter allocation of different *C. procera* plant organs, growing under different magnetic water treatments; (C= irrigation with 300ml nonmagnetic water, T_1= irrigation with 200ml nonmagnetic water+100ml magnetic water, T_2= irrigation with 100ml nonmagnetic water+200ml magnetic water and T_3= irrigation with 300ml magnetic water) in different growth stages; (seedling) = after 21 days, (Juvenile) = 45 days, (mature) = 90 days and (flowering) = 180 days. *P<0.05, **P<0.01, n.s. = non significant.

Growth stage† & treatment		% dry matter ± S.D.			
		leaves	stem	root	flowers
Seedling	**C**	8.76±0.92^{a}	43.81±2.03^{a}	47.42±2.05^{a}	------
	T_1	14.28±1.26^{a}	52.10±5.36^{a}	33.61±1.36^{b}	------
	T_2	6.82±0.09^{a}	65.65±4.22^{a}	27.52±0.94^{b}	------
	T_3	34.52±2.07^{b}	38.48±3.87^{a}	26.98±3.50^{b}	------
		*	n.s.	*	------
Juvenile	C	51.41±2.61^{ab}	35.41±6.89^{a}	13.17±1.02^{a}	------
	T_1	62.74±3.82^{a}	18.92±0.96^{a}	18.32±2.67^{a}	------
	T_2	63.64±4.20^{a}	31.23±1.68^{a}	5.12±0.04^{a}	------
	T_3	33.12±0.68^{b}	37.73±3.83^{a}	29.14±1.62^{a}	------
		**	n.s.	n.s.	------
Mature	C	13.59±0.06^{a}	62.13±3.67^{a}	24.26±2.08^{a}	------
	T_1	22.13±2.61^{a}	46.60±2.28^{b}	31.38±2.18^{a}	------
	T_2	28.74±0.83^{a}	41.02±0.91^{b}	30.22±3.67^{a}	------
	T_3	23.41±1.53^{a}	31.75±2.36^{b}	44.82±2.56^{a}	------
		n.s.	*	n.s.	------
Flowering	C	13.44±0.64^{a}	51.82±4.10^{a}	34.51±4.08^{a}	0.21±0.006^{a}
	T_1	3.98±0.34^{b}	83.29±8.37^{a}	11.31±0.68^{b}	1.41±0.67^{a}
	T_2	4.57±0.05^{b}	61.53±5.64^{a}	32.59±5.13^{ab}	1.29±0.02^{a}
	T_3	3.06±0.67^{b}	69.80±2.06^{a}	26.07±2.67^{b}	1.04±0.08^{a}
		*	n.s.	**	n.s.

App. Table 2. Relative growth rate (RGR), net assimilation rate (NAR) and leaf area ratio (LAR) of different *C. procera* growth stages (1= seedling-juvenile stage, 2= juvenile- mature stage, 3= mature- flowering stage), growing under different magnetic water treatments; (C= irrigation with 300ml nonmagnetic water, T_1= irrigation with 200ml nonmagnetic water+100ml magnetic water, T_2= irrigation with 100ml nonmagnetic water+200ml magnetic water and T_3= irrigation with 300ml magnetic water). *P<0.05, **P<0.01, n.s. = non significant.

Growth stage† & treatment		Growth parameter		
		RGR	NAR	LAR
1	C	0.1082[a]	4.42E-06[a]	24498.29[a]
	T_1	0.0667[b]	3.85E-06[ab]	17360.72[a]
	T_2	0.0662[b]	2.55E-06[a]	26016.88[a]
	T_3	0.0078[b]	5.32E-07[b]	14710.35[a]
		*	**	n.s.
2	C	0.0525[a]	5.1E-06[a]	10300.65[a]
	T_1	0.0643[a]	1.01E-05[b]	6368.592[b]
	T_2	0.0662[a]	1.05E-05[b]	6313.257[b]
	T_3	0.0732[a]	1.36E-05[b]	5369.629[ab]
		n.s.	*	**
3	C	0.0348[a]	5.92E-06[a]	5885.19[a]
	T_1	0.0208[b]	3.63E-06[b]	5740.79[a]
	T_2	0.0212[b]	5.22E-06[b]	4062.80[a]
	T_3	0.0131[a]	2.87E-06[b]	4592.07[a]
		*	*	n.s.

Discussion

Results of the current study demonstrated significant stimulating effects of magnetic water treatment on the root and shoot lengths of *C. procera* especially at the mature growth stage as compared to control plants treated by nonmagnetic irrigation water. This stimulating effect of magnetic water treatment can be explained by Alimi *et al*., (2009) who proved that the magnetic field treatment of water affects its physical properties (surface state, adsorptive power and conductivity) which in turn affect the permeability and other physiological aspects. This indicates that the efficiency of vegetative attributes were dependent on using magnetic water or nonmagnetic water in irrigation which was proved in the current study. In addition, the results of the present study proved the stimulating and positive enhancement of magnetic water on the plant growth of *C. procera* and that was in accordance with many authors (2012; Farrag *et al*., 2013, c; Mahmoud *et al.*, 2016). In addition, many studies such as Lixf *et al*., (2010), Yang *et al.*, (2012) and Farrag, (2013) revealed that the stimulating effects of the irrigation with magnetic water was directly related to the increase in enzyme activity and photosynthetic rates.

The present study showed that the root-shoot (R:S) ratio for all treated *C. procera* either by magnetic or nonmagnetic water at almost all growth stages was less than unity. This is in accordance with many authors like Hegazy *et al*., 2001

and Farrag 2013. That can be explained as the growth rate of shoot exceeds that of root (Sayed and Hegazy, 1994, Inderjit and Jacob, 2001). Moreover, Nilsson (1994) who suggested that the decrease in root/shoot ratio as a response to nutrient deficiency appears to be applied for plants subjected to various water interactions.

Comparing the dry matter allocation to the different plant organs of the *C. procera* control samples, with that irrigated with magnetic water, one can easily deduce that there is a general increase in the dry matter of different plant organs when irrigated with magnetic water. In addition, the current results showed that dry matter allocation of stem > leaves > root > flowers. Moreover, irrigation of the test species by magnetic water, significantly affected on the dry matter allocation of different plant organs especially leaves and stem and this effect increased and be more clear in the late growth stages (mature and flowering) than at the early growth stages (seedling and juvenile). These findings were in agreement with that of Yinan *et al.*, 2005; Farrag 2007 and Farrag, 2013. In addition, these findings could explained the positive effect of magnetic water on cell division, production of plant hormones, membrane permeability, germination, mineral uptake, movement of stomata, pigment synthesis, photosynthesis, respiration, protein synthesis, nitrogen fixation, specific enzyme activities and development of conductive tissues (Batanouny, 1999; Bharti *et al*., 2010; Chundattu *et al*., 2011; Farrag, 2013; Farrag *et al*., 2014; Mansour 2013).

Comparing the values of water contents of different *C. procera* organs showed that there is a general increase in the following order: leaves> flowers> stem> root. In addition, the water contents of the different plant organs recorded relatively higher values at the first three growth stages; namely, seedling, juvenile and mature growth stages as compared to late growth stage. These results coincided with the findings of Aladjadjiyan, 2002 and Alimi *et al*, 2006 and can be explained through the enhanced effect of the magnetic water on the rate of water imbibitions by seeds and the increase of permeability by roots (Farrag, 2013).

The present study revealed that less number of flowers per individual was recorded for the control *C. procera* plants by nonmagnetic water as compared with magnetic water plants. In this regard, many authors (Inderjit and Dakshini 1995; El-khatib and Abd-Elaah 1998; Hegazy *et al*. 2001; Thomas *et al.*, 2016) have reported the stimulating effects of magnetic water on the chlorophyll content and net photosynthetic rate of their test species which in turn affect the reproductive opportunity of the test species and as a result stimulation in reproductive organs was shown by plants treated by magnetic water. This feature is considered as a plastic response of the normal nonmagnetic water stressed plants which enables them to live but with a diminished reproductive growth (Raynal and Bazzaz 1975).

The current study showed significant increase in the number and area of *C. procera* leaves as affected by irrigation with magnetic as compared to those irrigated with normal nonmagnetic water. In this respect, many investigators coincide in their findings with our results *viz*, Aladjadjiyan, 2002 and Farrag, 2007.

The relative growth rate of plants is determined by their genetic background and by environmental conditions (Rafael *et al.* 2005). The RGRs of *C. procera* of the present work generally decreased with plant's age. This is in agreement with slow RGR that was observed by Hegazy and Ismail (1992) as a result of decreased age-specific LAR and slow NAR. This reflects the decreased amount of leaf production with age resulting in slower growth. On the other hand, The RGRs of *C. procera* control plants are generally higher than that of irrigated magnetic water plants, especially in case of the seedling and mature growth intervals. The slow RGR of treated plants may be implied by the increment of dry matter allocated to the leaves. This interpretes the higher RGR of control and mild treated plants as compared to higher quantities of magnetic water treated plants. Similarly, Sayed and Hegazy (1994), found that the pattern of RGR increment followed that of dry matter allocated into vegetative parts (stem and leaves) and a decrease in RGR resulted from an increased dry matter allocated to sexual structures (flowers and fruits) at the expense of vegetative parts. In addition, the reduced dry mass and RGR of rice with increased density of *lotus* rhizomes indicates a possible response to chemical interference (Hegazy *et al*. 2001).

In agreement with Farrag 2015, the variation of NAR among the studied *C. procera* was dependent on both amount of irrigated magnetic water and the growth interval. In addition, the highest LAR values were recorded in the first growth interval (seedling-juvenile), and then the values decreased in the subsequent growth intervals recording its minimal values in the third growth interval (mature-flowering stage). Moreover, the variation of NAR between different treatments of *C. procera* was very dynamic with age. Variability of NAR values among the test species was parallel to the fluctuations in the RGR values of most species. All test species attained the highest LAR values in the first growth interval, seedling-juvenile, and then values decreased in the subsequent growth intervals and this can be explained by the general trend of the increase of the leaf area values as the plants age. This is in agreement with findings of many authors e.g. Hegazy *et al*., 2001, Farrag, 2007, Farrag *et al*., 2013, c.

Water and soil analyses reported significant increase in most cations and anions in case of magnetic water application as compared to nonmagnetic one. This in turn increases the water solubility and consequently increases the test plant growth parameters (Li *et al*., 2015).

The effect of magnetic and nonmagnetic water on the chemical composition of *C. procera* plants was highly affected by the application of different concentrations as well as the type of water treatment. Comparing the obtained

data in case of using magnetic and nonmagnetic water, it was observed that irrigation of the test species by magnetic water increased the values of chemical ingredients such as: total carbohydrates, fiber, protein and lipid content. These results are in accordance with many authors e.g. El-Khatib and. Hegazy (1999), El-Darier, 2002, Pandey and Mishra, (2005), Al-Watban and Salama, (2012) and Farrag *et al.*, (2013, c). These stored compounds are broken down during germination and seedling growth by hydrolytic enzymes. Hence, magnetic water increases the enzyme activity of amylase and decrease the enzyme activities of protease and Peroxidase. Moreover, peroxidase activity of nonmagnetic water treated *C. procera* exceeded that of magnetic treated ones. In this respect, one may conclude that *C. procera* treated with nonmagnetic water were more stressed than those treated by magnetic water. In other words, treatment of *C. procera* plants by magnetic water stimulate the growth of the test species. These results are in agreement with many investigators (Baziramakenga *et al.*, 1997; Hegazy *et al.*, 2001; Einhelling, 2002; Bousquet-Mélou *et al*., 2005; Mushtaq *et al*., 2010 and Yang *et al*., 2012). In addition, magnetic water increases the adsorptive power of minerals, which is directly affecting the metabolic processes. Moreover, in most cases, magnetic water increase the element and metal contents of leaves as compared to those irrigated by nonmagnetic water except for iron and calcium.

The present study proved that the magnetic water stimulates the production of phytohormones (GA_3 and IAA) and most plant pigments especially chlorophylls as compared to *C. procera* samples irrigated by nonmagnetic water. These findings could be explained by Santos *et al.*, 2013, who mentioned that "the perturbations of vital functions, such as respiratory activity and photosynthesis have been revealed as good indicators of cytotoxicity". In other words, *C. procera* plants treated by magnetic water became more vital than those treated by nonmagnetic water. Moreover, increase in phytohormones and photosynthetic pigments via subjecting the test species to magnetic water can explain its vigorous growth as compared to those treated by nonmagnetic water. This was in agreement with Farrag 2015 and Thomas *et al.*, 2016.

The higher chlorophyll content of *C. procera* samples treated by magnetic water was explained by their direct action on the enhancement of chloroplast functionality, which might, in turn, have been a consequence of a direct action of magnetic water at the level of photosystem II (Hill reactions) or of perturbations in electron transfer between photosynthetic electron transport chain complexes (Santos *et al*., 2013). Moreover, the more pronounced increase of chlorophyll a relative to chlorophyll b, as in most treated samples of the study species, in the presence of magnetic water should have led to an anomalous chlorophyll a/ chlorophyll b ratio, which might result in damage in the structural organization of light-harvesting complex and lead finally to plant growth (Dewez *et al*., 2003). Moreover, increase in chlorophylls leads to inecreased photosynthetic and enzymatic activities and finally increases the growth (Jagadeesh *et al*., 2015).

In the present work, strong effects were exerted by the magnetic water on photosynthetic pigments and phytohormones of *C. procera* leaves treated by different magnetic water treatments. This is in agreement with other studies on different plant species, such as that of Santos *et al.* (2013) on *Lemna gibba* but using C_{60} nanoparticles; on *L. minor* but using alumina nanoparticles (Qian *et al.*, 2013).

In conclusion, magnetic water showed stimulating effect on the growth parameters of *C. procera*. The present study recommends the use of magnetic water in irrigation of economic important plants like edible plants and medicinal plants like *C. procera*.

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إستجابات النمو لدى نبات العشار الطبي النامى تحت تأثير المعالجة بالمياه المغناطيسية

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يهدف البحث الى تقييم أثر المعالجة بالمياه المغناطيسية على نمو نبات العشار و مقارنة التأثيرات المختلفة لإستخدام المياه المغناطيسية على معايير النمو خلال المراحل المختلفة من عمر نبات الدراسة بالإضافة إلى تقييم أثراستخدام المياه المغناطيسية على التعبير عن النشاط الإنزيمي، الهرمونات النباتية، الأصباغ المختلفة والعديد من المظاهر الفسيولوجية الأخرى لنبات الدراسة. أثبتت الدراسة الحالية أن معالجة نبات العشار بالمياه المغناطيسية يزيد من إنتاجية المادة الجافة باتجاه الأوراق مقارنة بالأعضاء النباتية الأخرى كما ان إنتاجية نبات العشار المعالج بالري بالمياه المغناطيسية تزداد إذا ما قورنت بتلك المعالجة بمياه غير مغناطيسية. أثرت معالجة نبات الدراسة بالمياه المغناطيسية على المحتوى المائي للأعضاء النباتية بزيادة ذلك المحتوى طبقا للترتيب التالي: الأوراق> الأزهار> السيقان> الجذور ، كما أوضحت النتائج زيادة عدد ومساحة أوراق نبات الدراسة المعالج بالري بالمياه المغناطيسية. بينت الدراسة الحالية أن معدل النمو النوعي يقل تدريجيا مع تقدم النبات في العمر وبصورة أكبر في نبات العشار المعالج بالمياه المغناطيسية كما أثبتت الدراسة تغيرات في معدل التمثيل الضوئي النسبي و معدلات مساحة الأوراق لنبات العشار في النباتات المرويه بالمياه المغناطيسية إذا ما قورنت بتلك المعالجة بالمياه غير المغناطيسية. كشفت تحاليل التربة والمياه بالدراسة الحالية عن إرتفاع نسبة العناصر والمعادن الصغرى و الكبرى في العينات المعالجة بالمياه المغناطيسية والتي تعطي تأثيرا مباشرا لإرتفاع النشاط الإنزيمي و التمثيل الضوئي والأصباغ و الهرمونات النباتية في النباتات المعالجة بالمياه المغناطيسية وبخاصة عند مقارنتها بتلك المروية بالمياه غير المغناطيسية. بينت الدراسة الحالية إرتفاع نسبة المواد النشوية وانخفاض نسبة الدهون بالأعضاء النباتية لنبات العشار و المعالجة بالمياه المغناطيسية. أوضحت الدراسة أن معالجة نبات العشار بالمياه المغناطيسية ، يزيد من معدلات انتاج الفينولات و البرولين في أوراق نبات الدراسة.

أوصت الدراسة الحالية باستخدام المياه المغناطيسية في إنبات ونمو وانتاجية النباتات الإقتصادية والطبية الهامة كنبات العشار وذلك لزيادة انتاجية تلك النباتات.