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PARTIAL SUBSTITUTION OF CHEMICAL FERTILIZATION OF ROSELLE PLANT (*Hibiscus sabdariffa* L.) BY ORGANIC FERTILIZATION IN PRESENCE OF ASCORBIC ACID

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ABSTRACT

Two field experiments were conducted to evaluate the effect of different levels of organic fertilizer (5, 10 and 15 m^3 compost/fed.) when used with half dose of chemical fertilizer compare with full dose of chemical fertilizer in presence of ascorbic acid foliar spraying (0.0, 100 and 200ppm) on some growth parameters, yield and chemical constituents of roselle (*Hibiscus sabdariffa* L.) plants during 2011 and 2012 seasons. Interaction effects between ascorbic acid and the used fertilization treatments on growth and productivity were studied as well.

The results showed that either treatment of half chemical fertilizer dose+15m^3 compost/fed. or full chemical fertilizer dose significantly induced the highest values of plant height, number of leaves, branches and fruits /plant, leaves dry weight/plant, fresh and dry weight of branches and sepals/plant, seed yield/plant, seed fixed oil per plant and per fed., sepals anthocyanin and vitamin-C content, leaf N, P, K, Fe, Zn and Mn uptake, leaf total carbohydrates, total sugars, total free amino acids, auxins, gibberellins and cytokinins content, but they decreased the values of leaf abscisic acid, peroxidase, catalase and superoxide dismutase contents. However, the highest number of leaves, branches and fruits/plant, the heaviest leaves dry weight/plant, the heaviest fresh and dry weights of sepals/plant, the highest seed fixed oil content per plant and per fed., the highest sepals vitamin-C contents, the highest leaf N, K, Fe and Mn uptake, the highest values of chlorophyll a&b, carotenoids, total carbohydrates, total sugars, total free amino acids, gibberellins and cytokinins as well as the lowest values of abscisic acid, peroxidase and superoxide dismutase were recorded by half chemical fertilizer dose+15m^3 compost/fed. treatment combined with 200ppm ascorbic acid. Besides, the highest sepals anthocyanin content was recorded by the combined treatment between half chemical fertilizer dose+10m^3 compost/fed. and 200ppm ascorbic acid in both seasons. Moreover, the tallest plants, the heaviest fresh and dry weight of branches/plant, the highest seed yield/plant, the highest leaf P and Zn uptake and the highest leaf auxins content of roselle plants were scored by the full chemical fertilizer dose combined with 200ppm ascorbic acid, followed by the combined treatment between half chemical fertilizer dose+15m^3 compost/fed. and 200ppm ascorbic acid in both seasons.

Consequently, it could be safely treat roselle plants with the combined treatment between half dose of chemical fertilizer+15m^3 compost/fed. and ascorbic acid at 200 ppm for enhancing growth and productivity of this plant.

Keywords: Roselle, chemical & organic fertilization, antioxidants, growth, yeild, anthocyanin, and chemical composition.

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INTRODUCTION

Roselle (*Hibiscus sabdariffa*, L.) is one of the most important plants of the Malvaceae Family, which produce a fleshly red calyxes and epicalyxes (sepals). Rovesta (1936) stated that roselle is used as beverage because of its therapeutic properties since it contains citric acid and large amount of an emollient and sedative mucilage which permit rapid digestion, decrease hyperviscosity of blood and arterial pressure. The sepals are used for the preparation of hot and cold red drinks and obtaining the natural food coloring pigments such as anthocyanin compounds (Diab, 1968). Also, it is used as hypotensive agent since it lowers blood pressure without producing side effect (Sharaf, 1962). Furthermore, the seeds of roselle plants contain about 17-30% fixed oil which is similar in its properties to cotton seed oil (Hussin *et al.,* 1991). It has antimicrobial activities due to its phenolic compounds. It contains protein, fibers, calcium, iron, carotene, and vitamin-C (Fasoyiro *et al*. 2005). For the previously mentioned reasons, the cultivated area of roselle in Egypt is increasing gradually for local utilization and export. The interest of most investigators is to find out the most favorable conditions to get the best growth and yield of roselle plant.

Recently, a group of substances known as antioxidants or oxygen free radical scavaengers were applied to protect against adverse effects of environment, reactive oxygen spices (ROS) and oxidative stress such as ascorbic acid, citric acid, α tocopherol , glutathion and vitamins (Chen and Gallie, 2006).

On the other hand, antioxidants are one of the new methods enhanced plant growth and development, increased photosynthetic pigments thereby increased chlorophyll and productivity as well, (Inskbashi and Iwaya, 2006). Ascorbic acid is known as growth regulating factor that influences many biological processes. Price (1966) reported that, ascorbic acid increased nucleic acids content, especially RNA. It also influences the synthesis of enzymes, and protein. It acts as coenzyme in metabolic changes (Patil and Lall, 1973). In this concern, El-Kashlan (2013) reported that spraying *Tagetes patula* plants with ascorbic acid at 150ppm increased vegetative and flowering growth as well as chemical composition.

Recently, unconventional efforts are used to minimize the amounts of applied chemical fertilizers which applied to medicinal and aromatic plants in order to reduce production cost and environmental pollution without yield reduction. Therefore, the trend now is to use organic fertilizers.

Many investigators indicated that organic fertilizers could be applied as fertilizers, conditioners or both together. Organic fertilizers increase soil organic matter, particularly for the sandy soils in Egypt, which record less than 1% and hence improve the physical, chemical and biological properties. Consequently, the availability of nutrients for plants as well as soil characteristics should be improved (FAO, 1977).

The nutritional requirements of macronutrients for medicinal and aromatic plants were reported by many researchers. In this concern, El-Sakov *et al.* (2001) worked on some medicinal and aromatic plants, Kozera and Nowak (2004) on *Silybum marianum*, Ashorabadi, *et al.* (2003) on *Foeniculum vulgare*, Niakan *et al.* (2004) on *Mentha piperita*, Lee *et al.* (2005) on *Chrysanthemum boreale* and Gomaa and Youssef (2007a) on fennel plant, Amran (2013) on *Pelargonium graveolens* plants and El-Khyat (2013) on *Rosmarinus officinalis*. They concluded that NPK fertilizers had an important physiological and biochemical functions on structure of photosynthetic pigments, metabolism of carbohydrates and protein and these effects were observed with significant increase in growth, yield and essential oil content of the different plant species.

The present study is undertaken to measure the usefulness of supplementing organic fertilizers in the form of compost manure with half dose of chemical fertilizer in presence of ascorbic acid as anti-oxidant on growth and yield of roselle plants and to minimize consuming chemical fertilizers.

MATERIALS AND METHODS

This work was carried out at the Experimental Farm, Fac. Agric., Moshtohor Benha Univ. during 2011 and 2012 seasons to study the effect of foliar spray with ascorbic acid (vitamin-c) at rates of 0.0, 100 and 200 ppm and some fertilization treatments (chemical and organic fertilizers) on the growth and prodctivity of roselle (*Hibiscus sabdariffa*, L.) plants. Roselle seeds were obtained from Floriculture Farm, Horticulture Department, Faculty of Agriculture, Benha Univ. Seeds were sown in clay loam soils on mid April of each seasons in plots (1x1 m) containing two rows (50 cm width) every row had two hills (50 cm apart), and one month later, the plants were thinned, leaving only one seedling/hill. Physical and chemical analyses of the experimental soil were determined according to Jackson (1973) and Black *et al.* (1982), respectively. The obtained results of soil analyses are presented in Tables (a) and (b).

Table (a): Mechanical analysis of the experimental soil.

Parameters	Unit	Seasons	
		2011	2012
Coarse sand	%	2.94	3.01
Fine sand	%	17.98	17.34
Silt	%	25.14	24.68
Clay	%	53.94	54.97
Textural class	------	Clay loam	Clay loam

Table (b): Chemical analysis of the experimental soil.

Parameters	Unit	Seasons	
		2011	2012
$CaCo_3$	%	1.12	1.05
Organic matter	%	1.69	1.48
Available nitrogen	%	0.39	0.41
Available phosphorus	%	0.21	0.19
Available potassium	%	0.28	0.26
E-C	**$dS.m^{-1}$**	0.79	0.83
pH	--------------	7.58	7.69

This experiment was set up in a split plot design with three replicates. The main plot was empoloyed by four fertilization treatments i.e. full chemical fertilization dose; 100 kg/fed. ammonium nitrate (33.5% N) + 300 kg/fed. calcium super phosphate (15.5% P_2O_5) + 150 kg/fed. potassium sulphate (48% K_2O), half chemical fertilization dose+ organic fertilizer (compost (containing plant sources and cattle manure; 5 m^3/fed., the chemical properties of the tested compost are presented in Table (c)), half chemical fertilization dose+ organic fertilizer (compost; 10 m^3/fed.) and half chemical fertilization dose+ organic fertilizer (compost; 15 m^3/fed.). Whereas, the sub plot was devoted to three ascorbic acid sprays i.e., control (tap water), 100 and 200 ppm. The amount of N and K fertilizers were divided into three equal portions as side dressing and added at three dates on mid June, on mid July and on mid August, respectively of both seasons. However, the amount of P-fertilizer and compost were added to the soil before seed sowing during soil preparation. Ascorbic acid treatments were applied as foliar spray at 90, 105 and 120 days after planting, respectively.

Table (c): Chemical properties of the used compost:

Parameters	Ec $dS.m^{-1}$ (1:5)	pH (1:5)	Total C %	Total N %	Total P %	Total K %	Total Fe (ppm)	Total Zn (ppm)	C:N ratio
Reading	2.12	6.52	19.31	1.12	0.39	1.24	1314	212	17:1

Recorded data:

1-Plant growth

Plant height (cm.), number and dry weight of leaves (g.) number, fresh and dry weight of branches were taken at the beginning of flowering stage; September 7, 2011 and September 12, 2012.

2- Fruits yield

Number of fruits /plant, sepals fresh and dry weight/plant, seed yield/plant, seed fixed oil content per plant and per fed. were recorded at harvesting time (November 2, 2011 and November 9, 2012).

3- Chemical constituents

At harvesting time anthocyanin content was determined in air-dried roselle sepals according to the method described by Du and Francis (1973). The percentage of fixed oil in seeds was determined according to the method mentioned by A.O.A.C (1980). Also, Vitamin-C was determined in sepals as discribed in A.O.A.C. (1980). Sepals acidity (pH value) was determined according to Diab (1968). The percentage of N,P,K, and total carbohydrates% were determined in the dry leaves during flowering stage, where total nitrogen was determined using the modified MicroKieldahl method according to A.O.A.C. (1980). Phosphorus was determined colourimetrically in spectronic (20) spectrophotometer using the method described by Trouge and Meyer (1939). Whereas, K content was determined by flame photometer according to Brown and Lilleland (1946). Also, Fe, Zn, and Mn were determined in the digested samples by atomic absorption as described by Chapman and Paratt (1961). Total carbohydrates (mg/g D.W), total sugars (mg/g D.W), total free amino acids (mg/g F.W), chlorophll a&b and carotenoids (mg/g F.W), were determined in the leaves according to (Herbert *et al.* 1971, Thomas and Dutcher, 1924, Rosed,1957and A.O.A.C, 1980, respectively).

Endogenous phytohormones:

Endogenous phytohormones were quantitatively determined in roselle leaves at the beginning of flowering stage in the second season using High- Performance Liquid Chromato-graphy (HPLC) according to Koshioka *et al.* (1983) for auxin (IAA), gibberellins and abscisic acid (ABA), while cytokinins were determined according to Nicander *et al.* (1993).

Assay of enzymes activities:

Assay of catalase, peroxidase and superoxide dismutase and their activities were made according to the methods described by Cao *et al*. (2005) and calculated according to the method of Kong *et al.* (1999).

Statistical analysis:

All data obtained in both seasons of study were subjected to analysis of variance as factorial experiments in split plot design. L.S.D. method was used to differentiate means according to Snedecor and Cochran (1989).

RESULTS AND DISCUSSION

I-Vegetative growth parameters

Data in Tables (1&2) indicate that full chemical fertilizer dose treatment (F_1) achieved the tallest plant, the heaviest fresh and dry weight of branches /plant, followed by 50% NPK + 15m^3 compost /fed. treatment (F_4) in both seasons, whereas the highest number of leaves and branches/ plant and the heaviest dry weight of leaves were recorded by F_4, followed by F_1 treatment, in the first and second seasons. The differences between F_1 and F_4 were so small to reach the level of significant in both seasons. On contrary, the lowest values of these parameters were scored in most cases by 50% NPK+ 5m^3 compost/fed. treatment (F_2) in the two seasons. The remained treatment 50% NPK+ 10m^3 compost/fed. (F_3) occupied an intermediate position between the aforementioned treatments in both seasons. Concerning the effect of ascorbic acid treatments, data in Tables (1&2) show that plant height, number of leaves and branches/ plant, fresh weight of branches/plant and dry weight of leaves and branches were increased in the two seasons, due to the two used levels of ascorbic acid over those of control plants, with superiority for the high level (200 ppm) in the two seasons.

As for the interaction effect between fertilization and ascorbic treatments, data in the same Tables (1&2) reveal that all the combinations between fertilization and ascorbic acid succeeded in increasing the tested vegetative parameters of roselle plant in both seasons. However, the combined treatment between F_1 and ascorbic acid at 200 ppm gave the tallest plant (180.20 and 183.66) , the heaviest fresh weight of branches (1401 and 1606g), the heaviest dry weight of branches/ plant (246.3 and 274.0 g), followed by the combined treatment between F_4 and ascorbic acid at 200 ppm, in the first and second seasons, respectively.Parallely, the highest number of leaves / plant (171.8 and 183.7), the heaviest dry weight of leaves/

plant (31.86 and 34.96 g) and the highest number of branches/ plant (28.20 and 29.63) were registered by the combined treatment between F_4 and ascorbic acid at 200 ppm, followed by the combined treatment between F_1 and ascorbic acid at 200 ppm, in the first and second seasons, respectively. The differences between abovementioned two combined treatments were so small to reach the significant level in both seasons.

The aforementioned results of fertilization concerning vegetative growth are in parallel with those obtained by Kandeel (2004) on *Ocimum basilicum*, Niakan *et al.* (2004) on *Mentha piperita*, El-Maadawy (2007) on *Amaranthus tricolor*, El-Maadawy and Moursy (2007) on jojoba, Gomaa and Youssef (2007a) on fennel, Badran *et al.* (2007) on cumin, Gomaa and Youssef (2007b) on lovage, El-Shora (2009) on *Mentha piperita*, Abou El-Ghait *et al.* (2012) on indian fennel, Gendy *et al.* (2012) on roselle plants, Gendy *et al.* (2013) on guar plants, Mohamed *et al.* (2012) on *Stevia rebaudiana*, Amran (2013) on *Pelargonium graveolens* and El-Khyat (2013) on *Rosmarinus officinalis*.

On the other hand, the positive effects of ascorbic acid are in agreements with the findings of Deore and Bharud (1990) on fenugreek, Chadha *et al.* (1999) on *Tagetes erecta*, Tarraf *et al.* (1999) on lemongrass, El-khayat (2001) on roselle plants, Noby (2002) on *Delphinium ajacis*, Ahmed (2005) on majoram plants, Gomaa (2006) on *Crinum assiaticum*, Balbaa and Talaat (2007) on rosemary plants, Farag (2009) on canola plants, Khalil *et al.* (2010) on basil plants, Eid *et al.* (2011) on *Tagetes erecta* and El-Kashlan (2013) on *Tagetes patula*.

II-Yield parameters

1-Fruits number/ plant

Data in Table (3) reveal that the highest fruits number/ plant (68.60 and 77.72) was scored by F_4 treatment, followed by F_1 treatment (66.96 and 73.91), in the first and second seasons, respectively. Also, fruits number/ plant were greatly affected by spraying roselle plants with ascorbic acid treatments, particularly the high level as compared with unsprayed plants in the two seasons. As for the interaction effect between fertilization and ascorbic acid treatments, data in Table (3) show that all resulted combinations increased the fruits number / plant, especially those received the combined treatments between F_4 or F_1 and ascorbic acid at 200 ppm as compared with the other in both seasons.

2-Fresh and dry weights of sepals/ plant.

It is clear from data in Table (3) that the heaviest fresh and dry weights of sepals/ plant were recorded as a result of F_4 and F_1 treatments with non-significant differences between them in both seasons. Remarkably, both levels of ascorbic acid resulted in significant increments in these parameters, especially those received the high level as compared with un-treated plants in the two seasons. Generally, all resulted interactions between fertilization and ascorbic acid treatments statistically affected the fresh and dry weights of sepals/plant in both seasons. However, the heaviest fresh and dry weights of sepals/plant were gained by using the combined treatments between F_4 or F_1 and ascorbic acid at 200 ppm when compared with other combinations in both seasons.

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3-Seed parameters

Data in Table (4) realize that seed yield/plant and seed fixed oil content per plant and per feddan were greatly affected by using all studied fertilization treatments in both seasons. However , the highest seed yield / plant was recorded by F_1 treatment followed by F_4 treatment, whereas the highest seed fixed oil content per plant and per feddan were registered by F_4 treatment, followed by F_1 treatment in both seasons. In addition, spraying roselle plants with ascorbic acid significantly increased seed yield / plant and seed fixed oil content per plant and per feddan, particularly with high level in the two seasons. In general, the highest seed yield / plant was obtained by F_1 treatment combined with ascorbic acid at 200 ppm, followed by the combined treatment between F_4 and ascorbic acid at 200 ppm, whereas the highest values of seed fixed oil content per plant and per feddan were scored by F_4 treatment combined with ascorbic acid at 200 ppm, followed by the combined treatment between F_1 and ascorbic acid at 200 ppm in both seasons. The differences between the abovementioned two combined treatments were so small to reach the level of significant in both seasons.

These results are in close agreement with those reported by El-khayat (2001) on roselle plants, El-Khyat and Zaghloul (1999), Abd El-Latif (2002) on caraway, Abd El-kader and Ghaly (2003) on coriander, Ashorabadi *et al*. (2003) on *Foeniculum vulgare*, Gomaa and Youssef (2007a) on fennel plant and Badran *et al*. (2007) on cumin plant.

III- **Chemical constituents**:

1-Anthocyanin content

Data in Table (5) show that the highest anthocyanin content (180.79 mg/100g DW) was accumulated in sepals as a result of using F_4 treatment in the first season, and F_3 treatment (177.17 mg/100g DW) in the second one. The differences between all tested fertilizer treatments were not significant in both seasons. Additionally, both levels of ascorbic acid succeeded in increasing anthocyanin content of roselle sepals, especially the high level in both seasons. Generally, F_3 treatment combined with ascorbic acid at 200 ppm gave the highest values in this concern (192.30 and 187.33 in the first and second seasons , respectively), followed by the combined treatment between F_4 and ascorbic acid at 200 ppm (189.50 and 182.33 mg /100g DW, in the first and second seasons, respectively).

2- Vitamin C

Data in Table (5) indicate that the highest content of vitamin C (49.00 and 48.19 mg /100g DW) was recorded by F_4, followed by F_3 and F_1 treatments in the first and second seasons, respectively. Moreover, both levels of ascorbic acid significantly increased this parameter as compared with untreated plants in both seasons. Generally, F_4 treatment combined with ascorbic acid at 200 ppm showed to be the most effective one for inducing the highest sepals vitamin-C content (58.53 and 56.33 mg /100g DW, in the first and second seasons, respectively).

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3- Sepals acidity (pH value)

Data in Table (5) clear that all tested fertilization and ascorbic acid treatments as well as their interactions resulted in negligible effects in this parameter with non significant difference in both seasons. In general, the lowest pH values (2.17 and 2.16 in the first and second seasons, respectively) were scored by F_2 treatment provided with control plant (0.0 ppm ascorbic acid), whereas the highest pH value (2.39) was recorded by F_3 treatment and enriched with ascorbic acid at 200 ppm in the first season, and the combined treatment between F_3 and ascorbic acid at 100 ppm (2.43) in the second one.

4- Leaf N, P and K uptake

Data presented in Table (6) declare that the highest values of leaf N, P and K uptake of roselle plants were recorded by F_1 treatment, followed by F_4 treatment in most cases in the first and second seasons. On the reverse, the lowest values of these parameters were scored by F_2 treatment in both seasons. Also, all tested levels of ascorbic acid increased these parameters, especially the high level in both seasons. As for the interaction effect between fertilization and ascorbic acid treatments, data in Table (6) reveal that the greatest leaf N and K uptake of roselle plants were obtained by the combined treatment between F_4 and ascorbic acid at 200 ppm, followed by F_1 treatment and supported with ascorbic acid at 200 ppm as an average of both seasons, whereas the highest leaf P uptake were scored by F_1 treatment combined with ascorbic acid at 200ppm, followed by the combined treatment between F_4 and ascorbic acid at 200 ppm as an average of both seasons.

5- Leaf Fe, Zn and Mn uptake

Data in Table (7) reveal that the highest leaf Fe and Mn uptake of roselle plants were obtained by F_4 treatment, followed by F_1treatment in both seasons. On the opposite, the lowest values of these parameters were scored by F_2 treatment in both seasons. While, the highest leaf Zn uptake was gained by F_1 as an average of both seasons. Also, all tested levels of ascorbic acid increased these parameters, particularly the high level in both seasons. Concerning the interaction effect between fertilization and ascorbic acid treatments, data in Table (7) show that the greatest leaf Fe and Mn uptake of roselle plants were obtained by F_4 treatment combined with ascorbic acid at 200 ppm, followed by the combined treatment between F_1 and ascorbic acid at 200 ppm in both seasons, whereas the highest leaf Zn uptake were scored by F_1 treatment combined with ascorbic acid at 200ppm, followed by the combined treatment between F_4 and ascorbic acid at 200 ppm as an average of both seasons. The differences between the abovementioned combined treatments were not significant in both seasons.

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6-Photosynthetic pigments

Data in Table (8) indicate that different photosynthetic pigments as chlorophyll a, b and carotenoids were positively responded to foliar applications with ascorbic acid at 100 & 200 ppm and half chemical fertilizer dose + compost at 5, 10 &15m3/fed. treatments compared with control plants during the two assigned seasons. Also, the interaction between ascorbic acid at 200 ppm and half chemical fertilizer dose + compost at 15m^3/ fed. gave the highest value in the respect, comparing with individual application or the control plants. Moreover, increase of chlorophylls and carotenoids content may be enhanced photosynthesis efficiency and that is a good explain to the increasing of dry matter production.

7- Leaf total carbohydrates, total sugars and total free amino acids contents

Data in Table (9) clear that there were significant differences in leaf total carbohydrates, total sugars and total free amino acids contents as response to the studied fertilization treatments in both seasons. Meanwhile, the highest values of these parameters were scored by F_4 treatment, followed by F_1 treatment in both seasons. The differences between the abovementioned two treatments were so small to reach the level of significance, but the differences between any of these treatments and the rest treatments were significant in both seasons. With respect for the effect of ascorbic acid treatments, data in Table (9) show that both levels of ascorbic acid (100 and 200 ppm) resulted in significant increments in these parameters, with superiority for the high level in both seasons. As for the interaction effect between fertilization treatments and ascorbic acid treatments, data in Table (9) reveal that the highest values of total carbohydrates content (211.7 and 213.8 mg/g DW), total sugars content (36.63 and 38.43 mg/g FW) and total free amino acids content (20.92 and 19.57 mg/g FW) of roselle leaves were recorded by F_4 treatment combined with ascorbic acid at 200 ppm, followed by the combined treatment between F_1 and ascorbic acid at 200 ppm ,in the first and second seasons, respectively.

The aforementioned results of fertilization concerning chemical constituents are in parallel with those obtained by El-khayat (2001) on roselle plants, Kandeel (2004) on *Ocimum basilicum*, Niakan *et al.* (2004) on *Mentha piperita*, El-Maadawy (2007) on *Amaranthus tricolor*, El-Maadawy and Moursy (2007) on jojoba, Gomaa and Youssef (2007a) on fennel plant, Badran *et al.,* (2007) on cumin plant, Gomaa and Youssef (2007b) on lovage plants, El-Shora (2009) on *Mentha piperita*, Abou El-Ghait *et al.* (2012) on indian fennel plant, Gendy et al. (2012) on roselle plants, Mohamed *et al.* (2012) on *Stevia rebaudiana*, Amran (2013) on *Pelargonium graveolens* and El-Khyat (2013) on *Rosmarinus officinalis*.

The results of ascorbic acid are nearly similar to those obtained by Deore and Bharud (1990) on fenugreek plant, Chadha *et al.* (1999) on *Tagetes erecta*, Morais *et al.* (2002) on *Capsicum annum*, Ismail (2004) on *Beaucarnea recurvata*, Ahmed (2005) on majoram plants, Farag (2009) on canola plants, Khalil *et al*. (2010) on basil plants, Eid *et al.* (2011) on *Tagetes erecta* and El-Kashlan (2013) on *Tagetes patula*.

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8-**Endogenous phytohormones content**

Data in Table (10) reveal that the highest leaf auxins content (23.50 µg/g FW) was scored by F_1 treatment combined with ascorbic acid at 200 ppm, followed by the combined treatments between F_3 or F_4 and ascorbic acid at 200 ppm . On contrary, the lowest value of this parameter was gained by F_2 treatment and without ascorbic acid. Moreover, the greatest leaf gibberellins content (38.16µg/g FW) was scored by the combined treatment between F_4 and ascorbic acid at 200 ppm, followed by the combined treatment between F_1 and ascorbic acid at 200 ppm . On the reverse, the lowest leaf gibberellins content was scored by the combined treatment between F_2 and control (untreated plants). Similarly, the richest leaf cytokinins content (10.76 µg/g FW) was recorded by the combined treatment between F_4 and ascorbic acid at 200 ppm, followed by the combined treatment between F_1 and ascorbic acid at 200 ppm . As for abscisic acid data in Table (9) show that the lowest leaf abscisic acid content was registered by the combined treatment between F_4 and ascorbic acid at 200 ppm, while the highest value was scored by F_1 treatment and received no ascorbic acid treatment.

Improvement in different growth parameters of roselle plants under interaction treatments could be mainly attributed to reduction in the level of the growth inhibitor (abscisic acid) or to alteration of hormone profile under treatments. Moreover, the proportions of total promoters to the inhibitor were increased with different treatments. These results are in agreement with Aono *et al.* (1993) on *Nicotiana tabacum* and Gomaa and Mady (2008) on chamomile plants.

9-**Anti-oxidant enzymatic activity content**.

Data presented in Table (11) declare that leaf peroxidase content was greatly declined by F_4 treatment combined with ascorbic acid at 200 ppm, followed by the combined treatment between F_3 and ascorbic acid at 100 ppm. Remarkably, the lowest leaf catalase content (48.50 µg/g FW/h) was scored by F_4 treatment combined with ascorbic acid at 100 ppm, followed by the combined treatment between F_4 and ascorbic acid at 200 ppm. Parallely, the lowest leaf superoxide dismutase content (90.83 µg/g FW/h)) was recorded by the combined treatment between F_4 and ascorbic acid at 200 ppm, followed by the combined treatment between F_3 and ascorbic acid at 200 ppm. On contrary, the highest leaf peroxidase, catalase and superoxide dismutase contents were recorded by the combined treatment between F_1 and control. Generally, these reductions in enzymatic activity with different applied treatment might be due to direct scavenging function against the toxic free radical and/ or their promotional effects on synthesis of internal productive antioxidants, i.e., total sugars, total amino acids and carotenoids. Xu *et al.* (2006) mentioned that plants have evolved well- developed defense mechanisms against these reactive oxygen species (ROS), involving enzymatic and non- enzymatic scavenging systems. Moreover, superoxide dismutase (SOD), ascorbate peroxidase (APX), catalase (CAT) and glutathione reductase (GR) are key of enzymatic antioxidants.

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DISCUSSION

1-Effect of ascorbic acid

The beneficial effect of antioxidant (ascorbic acid) on roselle growth might be due to: (1) their action as co-factors for some specific enzymes, i.e., dismutase, catalase and peroxidase which catalyzed breakdown of the toxic H_2O_2, OH and CO_2 radicals (Elad, 1992), (2) their enhancement of cell division and/or cell enlargement (Arrigoni *et al.,* 1997), (3) DNA replication (Noctor and Fayer, 1998) and/or (4) may be due to their role as antioxidants in protecting chloroplasts from oxidative damage by free radicals (Aono *et al.,* 1993)

1-Effect of chemical fertilization

To interpret and evaluate the effect of nitrogen, phosphorus and potassium concerned in this study, on augmenting the different tested vegetative growth parameters, yield component parameters and chemical constituents of roselle plants, it is important to refer to the physiological roles of nitrogen, phosphorus and potassium in plant growth and development. Such three macronutrient elements are the common elements usually included in fertilizers (Cooke, 1982). Plant supplement with these macronutrients in form of fertilizers is necessary because the soil is usually in deficient of them due to plant removal leaching or they are not readily available for plants. Therefore, such addition of well balanced NPK fertilization quantities insured production of high productivity and chemical constituents of roselle plants.

Nitrogen is essential for plant growth and development as a constituent of many amino acids, enzymes and energy transfer materials such as chlorophyll, ADP and ATP. Growing plants must have nitrogen to form new cells and the rate of growth then becomes very nearly proportional to the rate at which nitrogen is supplied. Photosynthesis can produce soluble sugars from CO_2 and H_2O but the process can not go on to the production of proteins. Thus, a severe shortage of nitrogen will halt the processes of growth and reproduction, (Bidwell, 1974). Besides, supplying the plants with adequate quantities of N at right time tends to increase cell number and cell size with an overall increase in the vegetative growth production (Thompsond and Troch, 1975).

Phosphorus which has been called the key to life is essential for cell division and for development of meristimmatic tissues and it is very important for carbohydrate transformation due to multitude of phosphorylation reaction and to energy rich phosphate bond (Lambers *et al.,* 2000). Phosphorus in the cell becomes united with carbon, hydrogen, oxygen, nitrogen and other elements to form complex organic molecules. Cell cannot divide unless there is adequate phosphorus to form the extra nucleus, so, phosphorus deficiency causes stunting, delayed maturity and shriveled seeds. Phosphorus compounds are also essential for photosynthesis, the inter conversion of carbohydrates and related glycolysis, amino acid metabolism, fat metabolism and biological oxidation. Lack of phosphorus, therefore hampers metabolic processes, such as the conversion of sugars into starch and cellulose (Devlin, 1972).

Potassium is important for growth and elongation probably due to its function as an osmoticum and may react synergistically with IAA. Moreover, it promotes CO_2 assimilation and translocation of carbohydrates from the leaves to storage tissues (Mengel and Kirkby, 1987).

The role of NPK fertilization on promoting vegetative growth characters, enhancing yield component parameters and increasing growth, fruit yield and as well as stimulating the chemical constituents content of roselle plants could be explained by recognizing their fundamental involvement in the very large number of enzymatic reaction that depend onNPK fertilization . NPK reflected directly on increasing the content of total carbohydrates, total sugars and total free amino acids as well as NPK % in the leaves were indirectly the cause for enhancing the augmenting of all other vegetative growth traits, yield components of roselle plants.

3- Effect of organic fetilizers (compost)

When organic manures added as fertilizer, it led to decrease soil pH which in turn increasing solubility of nutrients for plant uptake, in some cases organic materials may act as low release fertilizer. Recently, on the way of sustainable agriculture with minimum effects, the use of organic manures (compost or chicken manure, ..etc) as natural soil amendments is recommended to replace the soluble chemical fertilizers. They improve the structure of weak-structured sandy soils and increase their water holding capacity. Also, they improve soil fertility, and stimulate root development, induce active biological conditions and enhancing activities of micro-organisms especially those involved in mineralization (Zheljazkov and Warman, 2004).

Generally, it is preferable from the previous results, that foliar application of ascorbic acid combined with the fertilizer treatment of half dose of chemical fertilizer+ 15 m^3/ fed. could play an important role in improving growth, yield and chemical constituents of roselle plants. Therefore, the present study strongly admit the use of such treatment to provide good and high exportation characteristics due to its safety role on human health.

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الأستبدال الجزئي للتسميد الكيماوي لنبات الكركديه بواسطه التسميد العضوي في وجود حمض الأسكوربيك

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*****قسم الأراضي والمياه - كلية الزراعة – جامعة بنها**

أجريت تجربتين حقليتين لتقييم تأثير اضافه مستويات مختلفه من الكمبوست(5 ،10 ، 15متر مكعب /فدان) عند استخدامها مع نصف جرعه السماد الكيماوي مقارنه بالجرعه الكامله في وجود الرش الورقي بحمض الأسكوربيك (صفر ،100 ، 200 جزء في المليون) علي النمو والمحصول والمحتوي الكيماوي لنبات الكركديه خلال موسمي2011 ، 2012. بالأضافه تم دراسه تأثير التفاعل بين الأسكوربيك ومعاملات التسميد علي النمو والمحصول والمحتوي الكيماوي للكركديه.

أوضحت النتائج أنه سواء استخدمت معامله نصف المعدل من التسميد الكيماوي +15 متر مكعب كمبوست أومعامله المعدل الكامل من التسميد الكيماوي قد سجلت أعلي القيم بالنسبه لطول النبات ،عدد الأوراق والأفرع والثمار للنبات والوزن الجاف للأوراق ،الوزن الطازج والجاف للأفرع والسبلات للنبات، محصول البذور للنبات ، ومحصول الزيت الثابت للنبات والفدان، محتوي السبلات من الأنثوسيانين وفيتامين سي ، محتوي الأوراق من النيتروجين والفوسفور والبوتاسيوم والحديد والزنك والمنجنيز الممتص ، ومحتوي الأوراق من الكربوهيدرات الكليه والسكريات الكليه والأحماض الأمينيه الكليه وكلورفيل أ،ب والكاروتيندات والجبريللين والسيتوكينين والأندول بالأضافه للحصول علي أقل القيم بالنسبه لمحتوي الأوراق من حمض الأبسيسيك ، ومحتوي الأوراق من الأنزيمات (Peroxidase ,Catalase, Superoxide dismutase) . وعموما وجد أن أعلي عدد من الأوراق والأفرع والثمار للنبات ، أكبر وزن جاف للأوراق /نبات وأكبر وزن طازج وجاف للسبلات/ نبات ، أعلي محتوي زيت ثابت للنبات والفدان ، وأعلي محتوي للأوراق من فيتامين سي، وأعلي محتوي الأوراق من النيتروجين والبوتاسيوم والحديد والمنجنيز الممتص وأعلي محتوي للأوراق من كلورفيل أ،ب والكاروتيندات، و أعلي محتوي للأوراق من الكربوهيدرات الكليه والسكريات الكليه والأحماض الأمينيه الكليه والجبريللين والسيتوكينين بالأضافه للحصول علي أقل محتوي للأوراق من حمض الأبسيسيك وانزيم (Peroxidase, Superoxide dismutase) قد تم الحصول عليهم باستخدام المعامله المختلطه بين معامله التسميد نصف المعدل من التسميد الكيماوي +15 متر مكعب كمبوست ومعامله الأسكوربيك اسيد بتركيز 200 جزء في المليون . كما تم الحصول علي أعلي محتوي للأنثوسيانين في السبلات باستخدام المعامله المختلطه بيت معامله التسميد نصف معدل التسميد الكيماوي +10 متر مكعب كمبوست والرش بالأسكوربيك اسيد بتركيز 200 جزء في المليون .علاوة علي ذلك فان أكبر طول للنبات ، وأكبر وزن طازج وجاف للأفرع ، أكبر محصول من البذزه/نبات وأكبر محتوي للأوراق من الفوسفور والزنك الممتص وأكبر محتوي للأوراق من الأكسين قد تم الحصول عليه باستخدام المعامله المختلطه بين المعدل الكامل من التسميد الكيماوي والرش بحمض الأسكوربيك بتركيز 200 جزء في المليون، يليها في ذلك استخدام المعامله المختلطه بين معامله التسميد نصف المعدل من التسميد الكيماوي15 + متر مكعب كمبوست /فدان والرش بحمض الأسكوربيك بتركيز 200 جزء في المليون في كلا الموسمين . وبناءا علي ما سبق فانه يمكن استخدام المعامله المختلطه بين نصف المعدل من التسميد الكيماوي +15 متر مكعب كمبوست /فدان والرش بحمض الأسكوربيك بتركيز 200 جزء في المليون للحصول علي أفضل نمو وانتاجيه لنبات الكركديه.

قام بتحكيم البحث

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أ.د / ايمان مختار ابو الغيط	**كلية الزراعة- مشتهر – جامعة بنها**

Table 1: Effect of ascorbic acid and fertilization treatments on plant height, leaves number/plant and leaves dry weight/plant (g) of roselle plants during 2011 and 2012 seasons.

First season (2011)													
Parameters		**Plant height (cm)**			**Mean**	**Leaves number/plant**			**Mean**	**D.W of leaves/plant (g)**			**Mean**
fertilization \ ascorbic acid		**control**	**Ascorbic acid at 100ppm**	**Ascorbic acid at 200ppm**		**control**	**Ascorbic acid at 100ppm**	**Ascorbic acid at 200ppm**		**control**	**Ascorbic acid at 100ppm**	**Ascorbic acid at 200ppm**	
F1 (chemical NPK)		163.8	176.3	180.2	173.4	158.4	164.2	171.6	164.7	25.23	26.94	30.13	27.43
F2(50%NPK+5m^3 compost/fed.)		154.9	159.7	162.4	159.0	118.6	129.2	124.4	124.1	18.06	20.14	23.63	20.61
F3(50%NPK+10m^{3}compost/fed.)		156.4	161.6	164.1	160.7	129.8	146.6	141.6	139.3	20.63	26.21	27.26	24.70
F4(50%NPK+15m^{3}compost/fed.)		159.7	165.1	168.3	164.4	157.3	165.8	171.8	165.0	24.80	29.03	31.86	28.56
Mean		158.7	165.7	168.8		141.0	151.5	152.4		22.18	25.58	28.22	
L.S.D at 0.05	For ascorbic acid	N.S				N.S				2.43			
	For fertilization	N.S				18.60				3.04			
	For interaction	25.11				26.31				4.31			
Second season (2012)													
F1 (chemical NPK)		171.8	179.2	183.7	178.2	164.3	172.8	175.4	170.8	25.06	28.30	32.56	28.64
F2(50%NPK+5m^3 compost/fed.)		158.4	164.4	167.3	163.4	116.9	121.6	161.2	133.2	18.13	21.93	30.16	23.41
F3(50%NPK+10m^{3}compost/fed.)		161.8	165.5	169.2	165.5	132.8	155.2	158.5	148.8	22.86	26.84	29.86	26.52
F4(50%NPK+15m^{3}compost/fed.)		164.3	169.7	173.4	169.1	161.5	178.3	183.7	174.5	26.50	31.92	34.96	31.13
Mean		164.1	169.7	173.4		143.9	157.0	169.7		23.14	27.25	31.89	
L.S.D at 0.05	For ascorbic acid	N.S				13.07				1.74			
	For fertilization	14.48				16.34				2.18			
	For interaction	20.47				23.11				3.08			

Table 2: Effect of ascorbic acid and fertilization treatments on number, fresh and dry weights of branches/plant of roselle plants during 2011 and 2012 seasons.

Parameters		Branches number/plant				F.W of branches/plant (g)				D.W of branches/plant (g)			
		First season (2011)											
fertilization \ ascorbic acid		control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm	Mean	control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm	Mean	control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm	Mean
F1 (chemical NPK)		20.14	22.63	26.90	23.22	1216	1371	1401	1329	223.8	242.8	246.3	237.6
F2(50%NPK+5m^3 compost/fed.)		17.60	19.13	20.23	18.99	921	940	1069	977	163.9	170.9	193.4	176.1
F3(50%NPK+10m^{3}compost/fed.)		19.12	21.26	23.13	21.17	965	1108	1208	1094	174.6	201.5	219.2	198.4
F4(50%NPK+15m^{3}compost/fed.)		21.23	24.43	28.20	24.62	1232	1348	1373	1318	226.7	240.9	243.6	237.1
Mean		19.52	21.86	24.62		1084	1192	1263		197.3	214.0	225.6	
L.S.D at 0.05	For ascorbic acid	1.76				96.4				15.72			
	For fertilization	2.20				120.5				19.65			
	For interaction	3.11				170.5				27.78			
		Second season (2012)											
F1 (chemical NPK)		21.74	25.20	27.76	24.90	1246	1445	1606	1432	214.3	249.4	274.0	245.9
F2(50%NPK+5m^3 compost/fed.)		18.76	24.30	21.43	21.50	997	1008	1296	1100	171.4	168.7	226.4	188.8
F3(50%NPK+10m^{3}compost/fed.)		19.84	23.13	25.16	22.71	1018	1175	1242	1145	181.2	206.3	218.3	201.9
F4(50%NPK+15m^{3}compost/fed.)		22.15	26.36	29.63	26.05	1284	1391	1478	1384	227.1	246.6	258.8	244.2
Mean		20.62	24.75	26.00		1136	1255	1406		198.5	217.8	244.4	
L.S.D at 0.05	For ascorbic acid	2.29				103.7				14.06			
	For fertilization	2.87				129.9				17.58			
	For interaction	4.05				183.7				24.86			

Table 3: Effect of ascorbic acid and fertilization treatments on number of fruits /plant, sepals fresh and dry weights/plant of roselle during 2011 and 2012 seasons.

Parameters	Number of fruits /plant				Sepals fresh weight/plant (g)				Sepals dry weight/plant (g)			
	First season (2011)											
fertilization \ ascorbic acid	control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm	Mean	control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm	Mean	control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm	Mean

F1 (chemical NPK)	59.83	67.90	73.16	66.96	148.2	168.3	191.6	169.4	26.26	29.28	34.73	30.09
F2(50%NPK+5m^3 compost/fed.)	51.24	54.16	57.16	54.19	118.7	131.9	154.5	135.0	21.33	23.47	28.36	24.39
F3(50%NPK+10m^{3}compost/fed.)	53.60	59.76	66.26	59.87	132.7	152.7	178.3	154.6	24.36	28.11	32.83	28.43
F4(50%NPK+15m^{3}compost/fed.)	61.27	69.36	75.16	68.60	149.2	169.6	192.1	170.3	27.36	31.54	35.36	31.42
Mean	56.49	62.80	67.94		137.2	155.6	179.1		24.83	28.10	32.82	
L.S.D at 0.05 For ascorbic acid	4.75				10.79				2.47			
For fertilization	5.94				13.49				3.09			
For interaction	8.39				19.07				4.36			
Second season (2012)												
F1 (chemical NPK)	69.53	76.46	75.73	73.91	173.3	192.9	196.5	187.6	32.36	34.12	36.83	34.44
F2(50%NPK+5m^3 compost/fed.)	62.11	66.30	59.73	62.71	151.8	163.5	152.5	155.9	28.16	28.06	28.23	28.15
F3(50%NPK+10m^{3}compost/fed.)	61.70	64.36	71.36	65.81	146.9	162.9	201.3	170.4	27.43	29.00	36.93	31.12
F4(50%NPK+15m^{3}compost/fed.)	72.16	79.56	81.43	77.72	173.3	201.1	207.7	194.0	32.50	36.52	37.76	35.59
Mean	66.38	71.67	72.06		161.3	180.1	189.5		30.11	31.93	34.94	
L.S.D at 0.05 For ascorbic acid	3.67				17.59				2.45			
For fertilization	4.59				21.99				3.06			
For interaction	6.48				31.09				4.33			

Table 4: Effect of ascorbic acid and fertilization treatments on seed yield per plant and seeds fixed oil content per plant and fed. of roselle plants during 2011 and 2012 seasons.

First season (2011)												
Parameters	**Seed yield/plant (g)**			**Mean**	**Seed fixed oil content(ml/plant)**			**Mean**	**Seed fixed oil content (l/fed)**			**Mean**
ascorbic acid / fertilization	**control**	**Ascorbic acid at 100ppm**	**Ascorbic acid at 200ppm**		**control**	**Ascorbic acid at 100ppm**	**Ascorbic acid at 200ppm**		**control**	**Ascorbic acid at 100ppm**	**Ascorbic acid at 200ppm**	
F1 (chemical NPK)	41.04	47.04	53.76	47.28	5.53	6.39	7.36	6.43	92.90	107.35	123.65	107.97
F2(50%NPK+5m^3 compost/fed.)	33.14	36.93	44.60	38.22	4.78	5.37	6.64	5.60	80.30	90.22	111.55	94.02
F3(50%NPK+10m^{3}compost/fed.)	38.28	44.00	51.62	44.63	5.32	6.46	7.59	6.46	89.38	108.53	127.51	108.47
F4(50%NPK+15m^{3}compost/fed.)	40.30	47.81	52.17	46.76	5.94	7.01	7.82	6.92	99.79	117.77	131.38	116.31

Mean		38.19	43.95	50.54		5.39	6.31	7.35		90.59	105.97	123.52	
L.S.D at 0.05	For ascorbic acid	3.29				0.345				5.80			
	For fertilization	4.12				0.431				7.24			
	For the interaction	5.84				0.612				10.28			
Second season (2012)													
F1 (chemical NPK)		46.71	52.68	53.92	51.10	6.17	7.02	7.36	6.85	103.66	117.94	123.65	115.08
F2(50%NPK+5m^3 compost/fed.)		42.28	44.01	41.40	42.56	5.96	6.38	6.30	6.21	100.13	107.18	105.84	104.38
F3(50%NPK+10m^{3}compost/fed.)		42.34	45.36	50.28	45.99	6.31	6.97	7.32	6.87	106.01	117.10	122.98	115.36
F4(50%NPK+15m^{3}compost/fed.)		47.44	51.14	52.89	50.49	7.05	7.83	7.96	7.61	118.44	131.54	133.73	127.90
Mean		44.69	48.30	49.62		6.37	7.05	7.24		107.06	118.44	121.55	
L.S.D at 0.05	For ascorbic acid	2.96				0.337				5.66			
	For fertilization	3.71				0.422				7.10			
	For the interaction	5.26				0.598				10.05			

Table 5: Effect of ascorbic acid and fertilization treatments on anthocyanin, vitamin-C and sepals acidity of roselle plants during 2011 and 2012 seasons.

First season (2011)													
Parameters		**Anthocyanin (mg/100g DW)**			**Mean**	**Vitamin-C (mg/100g DW)**			**Mean**	**Sepals acidity (Ph value)**			**Mean**
ascorbic acid / fertilization		**control**	**Ascorbic acid at 100ppm**	**Ascorbic acid at 200ppm**		**control**	**Ascorbic acid at 100ppm**	**Ascorbic acid at 200ppm**		**control**	**Ascorbic acid at 100ppm**	**Ascorbic acid at 200ppm**	
F1 (chemical NPK)		173.20	184.16	181.46	179.61	42.56	46.20	52.30	47.02	2.27	2.32	2.28	2.29
F2(50%NPK+5m^3 compost/fed.)		169.40	186.33	174.33	176.69	41.30	43.20	41.80	42.10	2.17	2.41	2.12	2.23
F3(50%NPK+10m^{3}compost/fed.)		172.34	171.50	192.30	178.71	43.81	56.13	42.54	47.49	2.21	2.18	2.39	2.26
F4(50%NPK+15m^{3}compost/fed.)		174.51	178.36	189.50	180.79	42.32	46.16	58.53	49.00	2.19	2.34	2.37	2.30
Mean		172.36	180.09	184.40		42.51	47.92	48.79		2.21	2.31	2.29	
L.S.D at 0.05	For ascorbic acid	8.39				4.22				N.S			
	For fertilization	N.S				5.28				N.S			
	For interaction	14.88				7.48				N.S			
Second season (2012)													
F1 (chemical NPK)		168.36	178.30	176.30	174.32	40.74	47.46	51.33	46.51	2.23	2.39	2.26	2.29
F2(50%NPK+5m^3 compost/fed.)		165.18	180.80	169.50	171.83	41.92	44.23	41.26	42.47	2.16	2.31	2.18	2.22
F3(50%NPK+10m^{3}compost/fed.)		170.14	174.03	187.33	177.17	43.64	53.23	43.36	46.74	2.22	2.43	2.41	2.35
F4(50%NPK+15m^{3}compost/fed.)		172.46	174.53	182.33	176.44	42.92	45.33	56.33	48.19	2.21	2.36	2.34	2.30

Mean		169.04	176.92	178.87		42.31	47.56	48.07		2.21	2.37	2.30	
L.S.D at 0.05	For ascorbic acid	8.66				3.47				N.S			
	For fertilization	N.S				4.34				N.S			
	For interaction	15.36				6.19				N.S			

Table 6: Effect of ascorbic acid and fertilization treatments on leaf N, P and K uptake of roselle plants during 2011 and 2012 seasons.

First season (2011)													
Parameters		**Leaf N uptake (kg/fed.)**			**Mean**	**Leaf P uptake (kg/fed.)**			**Mean**	**Leaf K uptake (kg/fed.)**			**Mean**
ascorbic acid / fertilization		**control**	**Ascorbic acid at 100ppm**	**Ascorbic acid at 200ppm**		**control**	**Ascorbic acid at 100ppm**	**Ascorbic acid at 200ppm**		**control**	**Ascorbic acid at 100ppm**	**Ascorbic acid at 200ppm**	
F1 (chemical NPK)		7.16	7.83	9.57	8.19	1.45	1.87	2.19	1.84	12.46	14.66	16.05	14.39
F2(50%NPK+5m^3 compost/fed.)		4.58	5.18	6.39	5.38	0.93	1.06	1.25	1.08	7.95	8.46	9.81	8.74
F3(50%NPK+10m^{3}compost/fed.)		5.34	6.96	7.46	6.59	1.10	1.40	1.57	1.36	9.39	12.06	13.37	11.61
F4(50%NPK+15m^{3}compost/fed.)		6.62	8.24	9.74	8.20	1.31	1.58	2.07	1.65	11.37	13.80	16.49	13.89
Mean		5.93	7.05	8.29		1.20	1.48	1.77		10.29	12.25	13.93	
L.S.D at 0.05	For ascorbic acid	2.19				0.21				2.32			
	For fertilization	2.74				0.26				2.91			
	For interaction	3.87				0.37				4.10			
Second season (2012)													
F1 (chemical NPK)		6.82	8.89	10.61	8.77	1.36	1.84	2.28	1.83	11.79	14.69	17.29	14.59
F2(50%NPK+5m^3 compost/fed.)		4.33	5.45	7.96	5.91	0.92	1.12	1.66	1.23	7.37	9.28	13.02	9.89
F3(50%NPK+10m^{3}compost/fed.)		6.11	7.26	8.38	7.25	1.18	1.41	1.67	1.42	9.83	11.86	13.75	11.81
F4(50%NPK+15m^{3}compost/fed.)		6.95	9.22	10.69	8.95	1.41	1.84	2.07	1.77	11.31	15.23	17.21	14.58
Mean		6.05	7.71	9.41		1.22	1.55	1.92		10.07	12.77	15.32	
L.S.D at 0.05	For ascorbic acid	2.13				0.32				2.52			
	For fertilization	2.67				0.40				3.16			
	For interaction	3.77				0.57				4.46			

Table 7: Effect of ascorbic acid and fertilization treatments on leaf Fe, Zn and Mn uptake of roselle plants during 2011 and 2012 seasons.

Parameters		Leaf Fe uptake (g/fed.)			Mean	Leaf Zn uptake (g/fed.)			Mean	Leaf Mn uptake (g/fed.)			Mean
fertilization \ ascorbic acid		control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm		control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm		control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm	
First season (2011)													
F1 (chemical NPK)		322.1	371.1	440.4	377.9	173.8	203.7	248.0	208.5	76.3	95.0	116.4	95.9
F2(50%NPK+5m^3 compost/fed.)		206.3	240.2	313.6	253.4	97.1	132.0	146.9	125.3	42.5	64.3	67.5	58.1
F3(50%NPK+10m^{3}compost/fed.)		249.5	343.5	389.3	327.4	124.8	180.5	196.9	167.4	58.9	92.5	100.8	84.0
F4(50%NPK+15m^{3}compost/fed.)		325.0	409.7	476.4	403.7	162.5	209.7	240.9	204.4	79.2	107.3	128.5	105.0
Mean		275.7	341.1	404.9		139.5	181.5	208.2		64.2	89.8	103.3	
L.S.D at 0.05	For ascorbic acid	61.8				34.9				23.1			
	For fertilization	77.4				43.7				28.9			
	For interaction	109.3				61.7				40.8			
Second season (2012)													
F1 (chemical NPK)		332.6	385.1	486.8	401.5	193.7	233.0	284.4	237.0	71.6	90.3	109.4	90.4
F2(50%NPK+5m^3 compost/fed.)		219.3	291.1	390.2	300.2	94.4	132.6	187.5	138.2	36.6	58.9	86.1	60.5
F3(50%NPK+10m^{3}compost/fed.)		299.6	347.2	411.4	352.7	149.8	207.4	245.8	201.0	57.6	85.7	90.3	77.9
F4(50%NPK+15m^{3}compost/fed.)		360.6	445.1	511.0	438.9	187.0	246.7	281.9	238.5	80.1	101.9	123.3	101.8
Mean		303.0	367.1	449.8		156.2	204.9	249.9		61.5	84.2	102.3	
L.S.D at 0.05	For ascorbic acid	57.4				42.6				21.7			
	For fertilization	71.9				53.4				27.2			
	For interaction	101.5				75.3				38.4			

Table (8): Effect of ascorbic acid and fertilization treatments on photosynthetic pigments contents of roselle leaves during the two seasons of 2011 and 2012.

Parameters	Chlorophyll a (mg/g F.W)			Mean	Chlorophyll b (mg/g F.W)			Mean	Carotenoids (mg/g F.W)			Mean
ascorbic acid / fertilization	control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm		control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm		control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm	
First season (2011)												
F1 (chemical NPK)	0.465	0.533	0.584	0.527	0.283	0.342	0.372	0.332	0.262	0.317	0.342	0.307
F2(50%NPK+5m^3 compost/fed.)	0.405	0.435	0.472	0.437	0.234	0.246	0.287	0.256	0.228	0.232	0.254	0.238
F3(50%NPK+10m^{3}compost/fed.)	0.454	0.496	0.541	0.497	0.276	0.302	0.354	0.311	0.253	0.265	0.312	0.277
F4(50%NPK+15m^{3}compost/fed.)	0.486	0.558	0.645	0.563	0.294	0.357	0.394	0.348	0.274	0.334	0.365	0.324
Mean	0.453	0.506	0.561		0.273	0.312	0.352		0.254	0.287	0.318	
L.S.D at 0.05 For ascorbic acid	0.052				0.064				0.041			
L.S.D at 0.05 For fertilization	0.065				0.080				0.051			
L.S.D at 0.05 For interaction	0.092				0.123				0.072			
Second season (2012)												
F1 (chemical NPK)	0.472	0.543	0.592	0.536	0.289	0.356	0.384	0.343	0.269	0.325	0.349	0.314
F2(50%NPK+5m^3 compost/fed.)	0.418	0.442	0.483	0.448	0.242	0.253	0.292	0.262	0.231	0.236	0.263	0.243
F3(50%NPK+10m^{3}compost/fed.)	0.460	0.498	0.556	0.505	0.287	0.312	0.359	0.319	0.258	0.275	0.321	0.285
F4(50%NPK+15m^{3}compost/fed.)	0.495	0.567	0.634	0.565	0.296	0.362	0.397	0.352	0.282	0.342	0.362	0.329
Mean	0.461	0.516	0.566		0.279	0.321	0.358		0.260	0.295	0.324	
L.S.D at 0.05 For ascorbic acid	0.073				0.087				0.055			
L.S.D at 0.05 For fertilization	0.091				0.109				0.069			
L.S.D at 0.05 For interaction	0.128				0.153				0.097			

Table 9: Effect of ascorbic acid and fertilization treatments on total carbohydrates, total sugars and total free amino acids contents of roselle leaves during 2011 and 2012 seasons.

Parameters		Total carbohydrates mg/g dry weight			Mean	Total sugars mg/g fresh weight			Mean	Total free amino acids mg/g fresh weight			Mean
First season (2011)													
ascorbic acid / fertilization		control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm	Mean	control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm	Mean	control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm	Mean
F1 (chemical NPK)		174.3	190.7	206.5	190.5	25.71	29.52	33.25	29.49	15.98	17.38	19.85	17.74
F2(50%NPK+5m^3 compost/fed.)		131.5	144.5	152.6	142.9	19.55	22.74	21.65	21.31	12.45	13.65	12.52	12.87
F3(50%NPK+10m^{3}compost/fed.)		145.7	184.2	172.8	167.6	22.18	27.84	31.52	27.18	11.51	15.95	18.67	15.38
F4(50%NPK+15m^{3}compost/fed.)		176.4	196.3	211.7	194.8	26.12	30.42	36.83	31.81	15.72	19.25	20.92	18.63
Mean		157.0	178.9	185.9		23.39	27.63	30.81		13.92	16.56	17.99	
L.S.D at 0.05	ascorbic acid	21.84				1.88				1.16			
	fertilization	27.30				2.35				1.45			
	For the interaction	38.49				3.31				2.04			
Second season (2012)													
F1 (chemical NPK)		171.2	197.5	209.6	192.8	26.52	29.57	35.11	30.40	12.96	16.65	19.15	16.25
F2(50%NPK+5m^3 compost/fed.)		158.7	170.2	162.7	163.9	21.21	20.15	22.75	21.37	9.58	10.31	11.78	10.56
F3(50%NPK+10m^{3}compost/fed.)		153.5	189.4	193.4	178.8	28.96	28.21	32.25	29.81	10.68	14.68	16.60	13.99
F4(50%NPK+15m^{3}compost/fed.)		186.4	207.5	213.8	202.6	27.83	31.21	38.43	32.49	14.37	17.30	19.57	17.08
Mean		167.5	191.2	194.9		26.13	27.29	32.14		11.90	14.74	16.78	
L.S.D at 0.05	For ascorbic acid	22.56				1.65				1.22			
	For fertilization	28.20				2.06				1.53			
	For the interaction	39.76				2.91				2.15			

Table 10: Effect of ascorbic acid and fertilization treatments on endogenous phytohormones content of roselle leaves during 2012 season.

Parameters / Treatments	Promoters									Inhibitors		
	Auxins (µg/g FW)			Gibberellins (µg/g FW)			Cytokinins (µg/g FW)			Abscisic acid (µg/g FW)		
	control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm	control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm	control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm	control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm
F1 (chemical NPK)	18.60	20.94	23.50	29.42	33.50	36.28	8.22	8.73	9.56	1.38	1.27	1.19
F2(50%NPK+5m^3 compost/fed.)	13.72	17.22	19.28	27.70	31.52	29.60	5.49	6.73	7.11	1.12	0.96	0.84
F3(50%NPK+10m^{3}compost/fed.)	15.44	16.54	21.35	29.12	29.48	35.75	5.12	7.39	9.22	1.04	0.88	1.61
F4(50%NPK+15m^{3}compost/fed.)	15.24	18.96	20.50	32.15	32.15	38.16	6.35	9.18	10.76	1.06	0.85	0.64

Table 11: Effect of ascorbic acid and fertilization treatments on some anti-oxidant enzymatic activity contents of roselle leaves during 2012 season.

Parameters / Treatments	Anti-oxidant enzymatic activity								
	Peroxidase (µg/g FW/h)			Catalase (µg/g FW/h)			Superoxide dismutase (µg/g FW/h)		
	control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm	control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm	control	Ascorbic acid at 100ppm	Ascorbic acid at 200ppm
F1 (chemical NPK)	119.80	95.43	76.50	95.48	78.41	60.22	149.18	118.61	97.24
F2(50%NPK+5m^3 compost/fed.)	118.55	92.70	71.63	88.43	74.28	57.84	147.50	113.25	96.55
F3(50%NPK+10m^{3}compost/fed.)	105.45	66.57	80.30	83.50	70.54	65.32	136.35	114.30	91.78
F4(50%NPK+15m^{3}compost/fed.)	111.18	79.40	60.38	80.42	48.50	53.75	138.15	107.40	90.83