Physiological Study on Jerusalem Artichoke Plants (*Helianthus Tuberosus* L.) Under Two Types of Soils

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ABSTRACT

Two field experiments were carried out on Jerusalem artichoke crop during two successive seasons of 2016 and 2017 at Soil Salinity Laboratory Research, Agricultural Research Center, Alexandria Governorate, Egypt. Each experiment included sixteen treatments representing the combination of two types of soils; i.e., clay and calcareous, two trimming treatments; i.e., without trimming (T_0) and trimming (T_1) [removing of flowering buds before opening with 10-20 cm from ends of vegetative branches], and four fertilization treatments; i.e., 75 kg nitrogen/feddan + Halex-2 (F_1), 75 kg nitrogen/feddan + yeast extract (F_2), 75 kg nitrogen/feddan + Halex-2 + yeast extract (F_3) and 100 kg nitrogen/feddan (F_4). The experimental layout was presented as a split-split-plot in a randomized complete blocks design with three replicates. Two types of soil were assigned in the main plots; two trimming treatments were allocated to the sub-plots and four fertilization treatments which were, randomly, distributed in the sub-sub-plots. Planting Jerusalem artichoke tubers in clay soil encouraged each of the vegetative growth, yield and its component characters compared to planting in calcareous soil. Un-trimming Jerusalem artichoke growing plants resulted in positive effects on the vegetative characters, tubers' yield and its components traits compared to trimming treatment. Adding moderate amount of nitrogen fertilizer (75 kg N/ fed.) combined with Halex-2 plus yeast extract yielded statistically equal results if 100 kg N/fed. was added to the growing plants for most studied characters especially the economic ones. Maturity date trait did not affect with any of the applied treatments on Jerusalem artichoke growing plants. It turned out from the obtained results that a quarter of nitrogen fertilizer quantity could be saved by adding a mixture of bio-stimulants (Halex-2 + yeast extract) to the growing plants, in addition to un-trimming the ends of branching whether the cultivation was in clay or calcareous soils.

Key words: Jerusalem artichoke, trimming, bio-fertilizer, Halex-2 and yeast extract.

INTRODUCTION

Jerusalem artichoke (*Helianthus tuberosus* L.) is considered as an important non-traditional vegetable crop. It is a promising crop; especially it is grown in new reclaimed soils. Jerusalem artichoke tubers typically comprise about 80 % water. It may play an important role in human nutrition as sources for protein (1-2%), carbohydrates (15%), vitamins, inulin (up to 20 %) and minerals especially iron (0.4 to 3.7 mg 100 g–1), calcium (14 to 37 mg / 100 g) and potassium (420–657 mg / 100 g) (Baker *et al.*, 1990; Whitney and Rolfes, 1999 and Kocsis *et al.*, 2008). It also has beneficial medical effect, especially for diabetic patients. Also, Jerusalem artichoke can be used in food industry and important source for ethanol production (Rodrigues *et al.*, 2007).

The availability of plant nutrients are powerfully related to the properties of soils. Calcareous soils are one of the very important factors that limit the nutrients' availability. Calcareous soils are familiar in arid and semi-arid climates affecting more than 600 million ha soils of the world (Leytem and Mikkelsen, 2005). In calcareous soils where pH is high and $CaCO_3$ is dominated, plants suffer low availability of P and K would cause troubles more dangerous than their deficiencies. Micronutrients deficiency is one of the highly critical abiotic stresses in plants grown on calcareous soils (Xudan, 1986; Kulikova, *et al.*, 2002). Generally, calcareous soils are considered as very fragile with respect to agricultural production owing to their very low nutrients and organic matter content. Agricultural productivity on such soils is hence considerably low. Generally, Calcareous soils have low organic matter content and lack of nitrogen .Nitrogen fertilizer may be applied any time from just prior planting up to the time the plant is well established (FAO, 1977). Anyhow, the potential productivity of calcareous soils is high where sufficient water and nutrients can be provided.

Yeast as a natural stimulator is characterized by its richness in protein (47%), carbohydrates (33%), nucleic acid (8%), lipids (4%) and different minerals (8%) such as Na, Fe, Mg, K, P,S, Zn, Mn, Cu, Si, Cr, Ni, Va and Li, in addition to thiamin, riboflavin, pyridoxine, hormones and other growth regulating substances, such as biotin, B12 and folic acid (Nagodawithana, 1991). It also, considered a natural source of cytokinins and has stimulatory effects on bean plants (Amer, 2004). Foliar application of yeast could be of a great importance for plants grown under calcareous soil conditions. In this concern, yeasts have been stated to be rich source of

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phytohormones (especially cytokinins), vitamins, enzymes, amino acids and minerals (Barnett *et al*., 1990; Fathy and Farid, 1996; Khedr and Farid, 2000 and Mahmoud, 2001). Also, the stimulatory influences of yeast on cell division and enlargement, protein and nucleic acid synthesis and chlorophyll creation were informed by (Kraig and Haber, 1980, Castelfranco and Beale, 1983, Wanas, 2002 and Wanas, 2006). In another study, the usage of active yeast extract enriched growth and productivity of vegetable crops, due to its cytokinins content (Barnett *et al*., 1990). Yeast extract has stimulatory effects on plant growth and its productivity as reviewed by numerous authors on their studies on vegetative propagation crops (Ghoneim, 2005 on artichoke), (El-Ghinbihi and Ali, 2001, Taha and Omar, 2010 and Ahmed *et al*., 2011 on potatoes), and (Shalaby and El-Ramady, 2014 and Moussa *et al*., 2017on garlic).

Halex-2 is a bio-fertilizer which considers non-symbiotic nitrogen fixing bacteria (*Azospirillum*, *Azotobacter* and *Klebbsilla*). This bio-fertilizer has greater amounts of bacteria which responsible for fixing of nitrogen. Usage of Halex-2 to the cultivating plants attained the resulting values: increasing soil fertility, decreasing the usage of nitrogen fertilizers and expanding the availability of diverse nutrients to plant absorption (Abdel-Razzak and El-Sharkawy, 2013). Fayez *et al*. (1985) illustrated that free-living nitrogen fixing bacteria; e.g., *Azotobacter chroococcum* and *Azospirillum lipoferum*, were realized to have not only the capability to fix nitrogen but also the ability to release phytohormones similar to gibberellic acid and indole acetic acid which could motivate plant growth, absorption of nutrients and photosynthesis. Many researchers proved that utilizing bio-fertilizers (non-symbiotic nitrogen fixing bacteria) such as Halex 2, reflected positively effects on the vegetative growth, productivity and quality of numerous important vegetative propagation crops like potato (El-Gghinbihi and Ali, 2001 and Feleafel, 2005), globe artichoke (Ghoneim, 2005), and garlic (Moussa *et al*., 2017).

Trimming or pruning is the removal or reduction of certain plant parts that are not required, that are no longer effective, or that are of no use to the plant. Trimming (hand thinning of flowers) encourages plants to thrive. It has been known since the 1930s that the plant hormone auxin is released by the plant's actively growing tip and is transported down the main stem where it has an indirect effect on buds to inhibit branching (Reed, 2009). It is done to supply additional energy for the development of fruits, and limbs that remain on the plant. Trimming "pruning" or removing the ends of main branches growing points encouraged basal branching and accelerate branch growth (Rubinstein and Nagao, 1976; Wein and Minotti, 1988). A number of studies have taken care of this subject and reported the positive effects of trimming (pruning) on the vegetative growth characters, yield and its quality parameters (Olasantan, 1986; El-Assiouty, 1988 and Ghoneim, 2000 on okra plants and Barakat and Abdel-Razik, 1990 on tomato plants).

The present study was designed to investigate the effect of some cropping practice such as nitrogen, bio-fertilizers (Halex-2 and yeast extract) and trimming treatments on improving growth characteristics, tuber's yield and its components, as well as tubers' quality and chemical compositions of Jerusalem artichoke. Early maturity of the crop was also considered in this study through trimming treatment. Also, the objectives are to improve the productivity of Jerusalem artichoke plants by using lower doses of chemical nitrogen fertilizers compared to the recommended dose without any negative effects on the tubers' quality.

MATERIALS AND METHODS

Two experimental studies were carried out during the successive seasons of 2016 and 2017at Soil Salinity Laboratory Research, Alexandria, Agricultural Research Center. Tubers of Fuseau cultivar of Jerusalem artichoke were used in this study. The study was conducted in concrete lysimeters [1 m (L) x 1 m (W) x 2 m (D)]. Whole tubers within the weight range of 30-35 gram each were sown on the 1th of April during both seasons. Tubers' yield was harvested at the end of November. Each experiment included sixteen treatments representing the combination of two types of soils; i.e., clay and calcareous, two trimming treatments; i.e., without trimming (T_0) and trimming (T_1) and four fertilization treatments; i.e., 75 kg nitrogen/feddan + Halex-2 (F_1), 75 kg nitrogen/feddan + yeast extract (F_2), 75 kg nitrogen/feddan + Halex-2 + yeast extract (F_3) and 100 kg nitrogen/feddan (F_4). Tubers were planted one in each plot (experimental unit). During the two growing seasons, all other recommended agro-managements such as irrigation, disease pests and weed control were performed whenever they appeared to be necessary. Some of the physical and chemical properties of the two types of soils were measured using laboratory tests suggested by the U.S. Salinity Laboratory Staff (1954) are presented in Table (1).

Table 1. Some physical and chemical properties of the experimental soils (average of the two seasons)

Soil type	Physical properties: Sand %	Silt %	Clay %	Soil texture	pH	EC. dS/m	$CaCo_3$%	O.M.%
Calcareous	55	25	20	sandy clay loam	8.16	1.95	32.0	1.36
Clay	34	30	36	clay loam	7.84	1.63	2.80	2.14

Chemical properties

	Soluble cations (meq/L)				Anions (meq/L)				Soil available		
	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{-}	HCO_3^{-}	CL^{-}	SO_4^{--}	N%	P%	K%
Calcareous	6.40	4.62	5.95	1.22	-	8.01	7.75	2.43	0.32	0.15	0.48
Clay	4.80	3.80	5.40	0.68	-	5.54	5.76	3.38	0.56	0.32	0.40

Agricultural practices

The following fertilizers were added to the soil at preparation; 5 m^3 organic manure /fed., 75 Kg P_2O_5/fed.in the form of mono calcium phosphate (15.5 % P_2O_5) and 100 kg S/fed. Nitrogen fertilizer was added in the form of ammonium sulphate $(NH_4)_2SO_4$, 20.6% N) in three equal doses. The first dose was added one month after planting. The second and third doses were added two and three months later from the first dose. Potassium fertilizer was added at the rate of 120 Kg K_2O / fed. in two equal doses in the form of potassium sulphate (48% K_2O). The first dose was added with the second addition of nitrogen fertilizer, while the second half was added with the third dose of nitrogen fertilizer. Trimming treatment was done 5 months later from planting by removing the flowering buds before blooming with about 10-20 cm from the ends of the branches. This process lasted for two consecutive weeks (flowering stage).

Source of the bio-stimulants

Halex-2 is a bio-fertilizer comprised mixed inoculation of non-symbiotic N-fixing bacteria of genera *Azospirillum*, *Azotobacter* and *Klebsiella*. Halex-2 was kindly provided by the Bio-fertilization Unit, Department of Plant Pathology, The Faculty of Agriculture, Alexandria University. Egypt. Tubers were inoculated by soaking in suspension of the Halex-2 containing 5% Arabic gum, at the rate of 400 g/fed. for half an hour before planting according to the recommendation of the above mentioned department. The inoculation with Halex-2 was repeated two months later as side dressing beside the growing plants (Ghoneim, 2005).

Yeast extract:- The brewer’s yeast (*Saccharomyces cerevisiae*) was dissolved in water. Sugars were added to the yeast at a ratio of 1:1. The extract was kept for 24 hours in a warm place for reproduction, as explained by Morsi *et al*. (2008). The yeast extract was added as soon as tubers' planting. The yeast extract was added to the growing plants for the second time after two months from planting.

Measurements:

Vegetative growth and yield parameters:

Each plant in each experimental unit was taken to measure the studied vegetative growth characters (Plant height (m) and number of branches / plant), tubers' yield / feddan and yield components (average tuber weight / plant (kg) and number of tubers / plant). The vegetative growth characters were recorded on the growing plants at the end of flowering stage; while the data of the tubers' yield and its component characters were recorded at harvesting date. Maturity period (days) was determined by counting the days from planting till harvest of the crop.

Tubers' quality:

Random samples of ten tubers per treatment were randomly used. Percentage of tubers' dry weight calculated by drying 100 gm of fresh sliced tubers in an electric air – drying oven at 70 c˚ till constant weight. Each dried sample was ground to powder. Inulin content was determined in tubers according to the method of Winton and Winton (1958). Tubers' starch percentage (%) was determined using a sample of 1 g of dried tuber, according to the method described in A.O.A.C. (1990).

Tubers' mineral contents:

A sample of 0.5g from the ground material was digested with sulphuric acid by hydrogen peroxide according to Evenhuis and De Waard (1980). Aliquots were then taken for mineral determination. Nitrogen was determined according to A.O.A.C. (1990). Phosphorus was determined colorimetrically following Murphy and Riley (1962). Potassium was determined against a standard using air propane flame photometer following Chapman and Pratt (1961). The concentration of N, P and K were expressed as percentage.

Experimental design and statistical analysis

The experimental design used was a split-split-plot in a randomized complete blocks design (R.C.B.D) with three replicates. Two types of soil were assigned in the main plots; two trimming treatments were allocated to the sub-plots and four fertilization treatments which were, randomly, distributed in the sub-sub-plots. Collected data of the experiments were statistically analyzed using the analysis of variance method. Comparisons among the means of different treatments were done, using least significant differences (L.S.D) test procedure at p = 0.05 level of probability, as illustrated by Snedecor and Cochran (1980). Computation was done using Co-Stat software program (2004).

RESULTS AND DISCUSSION

Plant growth characters

Effects of soil types on the vegetative growth

The results of Table (2) showed that soil type had significant effects on the vegetative growth characters. The differences between soils types showed that plant height was significantly higher when Jerusalem artichoke plants were grown in clay soil during the two seasons.Same trend of results were also detected for number of branches / plant, where the highest mean value was given when Jerusalem artichoke plants were grown in clay soil during the two seasons. These results may be due to soil characteristics at most $CaCO_3$%, pH and texture. Soils with high values of $CaCO_3$% and pH may suffer from low availability of soil nutrients. Soil texture is the important properties of the soil and affects the rate of water absorption, aeration, micronutrient transport availability and soil fertility (Tan, 2003).

Effects of trimming treatments on the vegetative growth

The data of Table (2) showed that un-trimming treatment significantly gave the highest mean values for plant height trait during the two seasons. On the other side, there was insignificant differences between the two trimming treatments (trimming and un-trimming) for number of branches per plant character across the two seasons. The results of Ghoneim (2000) on okra plants and Al-Obidy (2011) on roselle plants appeared that decapitation pinching led to significant increments in most studied vegetative growth characters except for plant height. This may be due to the fact that pinching may limits the formation of gibberellin found in the developing peaks in the roots and the stems which responsible for plant elongation and the tendency of the plant to give lateral growth instead of longitudinal growth.

Effects of fertilization treatments on the vegetative growth

As for plant height and number of branches/ plant traits, the recorded data showed that both the fertilization treatments F_3 and F_4 significantly possessed the highest mean values during the two seasons; while both the fertilization treatments F_1 and F_2 gave the lowest mean values (Table, 2). It turned out from the previous results the role of the applied bio-stimulants as a mixture of Halex-2 and yeast extract on the positive stimulation of the vegetative growth characteristics of Jerusalem artichoke plants. This result is accordance with those obtained by Ghoneim (2005) and Shafeek *et al*. (2012). The authors demonstrated that inoculation the growing plants with bio-fertilizers simulative the vegetative growth characters. Shafeek *et al*. (2012) explained that this superiority may be assigned to the microorganisms' inoculation, in the first place, enriched the rhizosphere with these bacteria. Furthermore, these microbial inoculation encourage plant growth either directly, by producing plant hormones and improving nutrient uptake, or indirectly, by altering the microbial balance in rhizosphere in favor of the useful microorganisms (Amara *et al*., 1995 and Lazarovits and Nowak 1997). Furthermore, N-biofertilizer bacteria enhanced the plant growth by N-fixing in the cultivated soil and /or contributing some growth hormones like gibberellins, auxins and cytokinins (Cacciari *et al*. 1989). Recently, this beneficial effect was compatible with those obtained with Zhongyong *et al*. (2006), Luo *et al*. (2008) and Leaungvutiviroj *et al*. (2010) on cassava plants.

Effects of interactions on the vegetative growth

The obtained data of Table (2) illustrated that the interactions between soil types and trimming treatments were significant for the studied vegetative characters. The interaction (clay x T_0) significantly gave the highest mean values for plant height. As for number of branches / plant; the recorded data showed that the two interactions (clay x T_1) and (clay x T_0) significantly gave the highest mean values during the two seasons. The results of the interaction between soil type and fertilization treatment (Table, 2) showed that, the two interactions (clay x F_3) and (clay x F_4) significantly gave the highest mean values for both plant height and number of branches / plant traits during the two seasons. The results of Table (2) for plant height character showed that, the interactions (T_0 x F_3) and (T_0 x F_4) significantly gave the highest mean values during the two seasons. With regard to number of branches / plant, the results of the two seasons showed that each of the interactions (T_1 xF_3), (T_1 xF_4), (T_0 x F_3) and (T_0 x F_4) significantly possessed the highest mean values in this respect. Generally, it is clear from the previous results that there is a positive effect of un-trimming treatment in its interaction with the soil types or with fertilization treatments on the effect of the studied vegetative traits. The positive effect of bio-stimulants as a mixture of Halex-2 and yeast extract was also demonstrated through its interaction with the soil types or with the trimming treatments. The positive effects of tested bio-stimulants on the vegetative characters were mainly due to the role of Halex-2 in increasing the availability of N to plant absorption and containing yeast cytokinins, enzymes, vitamins, minerals and amino acids which have positive role on cell division and elongation, nucleic acid synthesis, protein and chlorophyll formation (Khedr and Farid, 2000, Mahmoud, 2001).

Generally, the interactions between soil types x trimming treatments x fertilization treatments showed significant effects for plant height and number of branches / plant across the two seasons of this study (Table, 2). The interactions (clay x T_0 x F_3) and (clay x T_0 x F_4) significantly gave the highest mean values for plant height trait during the first season. As for the second season, the results showed that the three interactions (clay x T_1 x F_4), (clay x T_0 x F_3) and (clay x T_0 x F_4) were superior to the rest of the tested interactions. As for number of branches / plant, it appears from the data of Table (2) that the each of the interactions (clay x T_1 x F_3), (clay x T_1 x F_4), (clay x T_0 x F_3) and (clay x T_0 x F_4) significantly possessed the highest mean values during the two seasons. The results of (Tony, 2013) showed that the bio-stimulants improved plant height and some other vegetative characters of Jerusalem artichoke plants only when 50% of the N recommended dose was applied. The results of Table (2) illustrated that the interaction formulations containing mixture of bio-stimulants (Halex-2 and yeast extract) statistically gave results equal to the treatment containing 100% of the recommended amount of nitrogen (100 kg nitrogen/feddan) for the vegetative traits. Bio-fertilizers able to enhance vegetative growth, mineral nutrient uptake and improve the yielding of many plants (Fayad, 2005; Fathy *et al*., 2008 and Hassan *et al.*, 2008). Many researches proved the benefit role of yeast extract on stimulating the vegetative growth of plants; i.e., Ghoneim, (2005) on artichoke; El-Ghinbihi and Ali (2001), Taha and Omar (2010) and Ahmed *et al*. (2011) on potatoes. The authors illustrated that yeast extract had favorable influence on the plant metabolism and biological activity through stimulating photosynthetic pigments and enzyme activity which in turn promote the plant vigorous. Apte and Shende (1981) reported that the inoculation substances might change the microflora in the rhizosphere and affect the balance between harmful and beneficial organisms. Similar findings were recorded by Sorial *et al.* (1998), on globe artichoke who indicated that the application of Promote bio-fertilizer; mixtures of fungus and yeast; significantly stimulated plant height, number of leaves /plant and leaf dry matter content.

Table 2.Mean performances of the vegetative characters of Jerusalem artichoke plants during the seasons of 2016 and 2017

Treatments			Plant height (m)		No. of branches/ plant	
Soil type	Trimming	Fertilization treatments				
			Seasons			
			2016	2017	2016	2017
Calcareous			2.63b	2.49b	15.63b	13.04b
Clay			3.23a	2.89a	18.50a	15.38a
	T_1		2.85b	2.54b	17.25a	14.38a
	T_0		3.02a	2.84a	16.88a	14.04a
		F_1	2.86b	2.50b	16.17b	13.08b
		F_2	2.76c	2.43b	15.75b	12.83b
		F_3	3.04a	2.89a	18.17a	15.25a
		F_4	3.05a	2.95a	18.17a	15.67a
Calcareous	T_1		2.52d	2.36c	15.67b	13.08b
	T_0		2.74c	2.62b	15.58b	13.00b
Clay	T_1		3.17b	2.73b	18.83a	15.08a
	T_0		3.29a	3.06a	18.17a	15.67a

Cont. Table 2.

Treatments			Plant height (m)		No. of branches/ plant	
Soil type	Trimming	Fertilization treatments				
			Seasons			
			2016	2017	2016	2017
Calcareous		F_1	2.51e	2.37c	14.83c	11.83c
		F_2	2.37f	2.24c	14.33c	11.67c
		F_3	2.82d	2.65b	16.67b	14.17b
		F_4	2.83d	2.70b	16.67b	14.50b
Clay		F_1	3.22b	2.62b	17.50b	14.33b
		F_2	3.16c	2.62b	17.17b	14.00b
		F_3	3.27a	3.13a	19.67a	16.33a
		F_4	3.28a	3.21a	19.67a	16.83a
	T_1	F_1	2.77d	2.25d	16.33b	13.17b
		F_2	2.67e	2.35cd	16.17b	13.17b
		F_3	2.97b	2.75b	18.33a	15.33a
		F_4	2.97b	2.82b	18.17a	15.83a
	T_0	F_1	2.96b	2.74b	16.00b	13.00b
		F_2	2.86c	2.50c	15.33b	12.50b
		F_3	3.12a	3.03a	18.00a	15.17a
		F_4	3.13a	3.09a	18.17a	15.50a
Calcareous	T_1	F_1	2.37i	2.20hi	15.00def	12.00d
		F_2	2.23j	2.17i	14.67ef	12.00d
		F_3	2.73f	2.50fgh	16.67cd	14.00c
		F_4	2.75f	2.57efg	16.33cde	14.33c
Calcareous	T_0	F_1	2.66g	2.54efg	14.67ef	11.67d
		F_2	2.51h	2.31ghi	14.00f	11.33d
		F_3	2.90e	2.80cdef	16.67cd	14.33c
		F_4	2.91e	2.83cde	17.00c	14.67bc
Clay	T_1	F_1	3.17cd	2.30ghi	17.67bc	14.33c
		F_2	3.11d	2.53efg	17.67bc	14.33c
		F_3	3.20bc	3.00bc	20.00a	16.67a
		F_4	3.20bc	3.07abc	20.00a	17.33a
Clay	T_0	F_1	3.26b	2.93cd	17.33c	14.33c
		F_2	3.20bc	2.70def	16.67cd	13.67c
		F_3	3.35a	3.26ab	19.33ab	16.00ab
		F_4	3.36a	3.35a	19.33ab	16.33a

* Values marked with the same alphabetical letter (s), within a comparable group of means, are not significantly different, using L.S.D. test at P=0.05 level.

Productivity and its component characters

Effects of soil types on yield and yield component characters

The results of Table (3) showed that soil types had positively significant effects on number of tubers / plant and tubers' yield / feddan traits during the two seasons. The data regarding average tuber weight appeared that this trait affected with soil types only during the second season. The obtained data showed that cultivation of Jerusalem artichoke tubers in clay soil resulted in a significant increase in the number of tubers per plant and the tubers' yield / feddan compared to the cultivation in calcareous soil. There was no significant effect of the soil type treatment on the maturity of Jerusalem artichoke plants.

Effects of trimming treatments on yield and yield component characters

Generally, un-trimming treatment significantly possessed positive effects on tubers' yield /feddan trait and its component character (number of tubers / plant) during the two seasons (Table, 3).There were no significant effects of trimming treatments on the average tuber weight character during the second season or on the maturity trait during the two seasons. Gonzales, *et al*. (1977) reported that topping reduced sweet potato tuber yields; where, the highest production was obtained with no topping. Olasantan and Salaua (2007) illustrated through their experience on okra plants that quarter or half pruning from the upper parts of the main stems of apically debudded plants to stimulate the plants to produce high yielding. The results of Suleiman and Alhaji (2015) revealed that the highest yield of okra and the largest number and weight of pods was produced from growing point pinching comparing with the without pinching.

Effects of fertilization treatments on yield and yield component characters

As for number of tubers / plant and tubers' yield / feddan traits, the results of Table (3) clearly demonstrated the superiority of the two fertilization treatments F_3 and F_4 to the rest of the tested fertilization treatments during the two seasons of this study. The same two fertilization treatments also surpassed the rest of the fertilization treatments during the first season for the average tuber weight (Table, 3). There were no significant differences between the tested fertilization treatments for the average tuber weight during the second season or on the maturity trait during the two seasons. Dorrell and Chubey (1977) found moderate or no yield increases due to increasing nutrient supply. In spite of the huge additions of chemical fertilizers to the cultivated soil in Egypt, the available nutrients level for plants is usually low, since it is rapidly converted to an unavailable form by its reaction with other soil constituents and conditions and becomes inaccessible by plants (El-Dahtory *et al*., 1989). Nitrogen is an essential element for plant growth and development.

Effects of interactions on yield and yield component characters

The data of the interaction soil types x trimming treatments (Table, 3) cleared that the interaction (clay x T_0) significantly possessed the highest mean value for both tubers' number / plant and tubers' yield / feddan during the two seasons. Average tuber weight character significantly affected with the interaction between soil type x trimming treatments during the two seasons; where, the interactions (calcareous x T_0) and (clay x T_0) significantly gave the highest mean values for average tuber weight character during the first season. The data of the second season appeared that the interaction (clay x T_1) significantly gave the highest mean value for the average tuber weight without significant differences with the interaction (clay x T_0). As for the interactions soil types x fertilization treatments, the data of Table (3) showed that the two interactions (clay x F_3) and (clay x F_4) significantly possessed the highest mean values for the number of tubers / plant and tubers' yield / feddan through the two seasons. In terms of the first season for the average tuber weight character, the obtained data indicated that there were not significant differences among the tested interactions except for the interaction (calcareous x F_2) (calcareous x F_4) which significantly gave the lowest value in this respect. Each of the following interactions; (calcareous x F_1), (calcareous x F_2), (clay x F_1), (clay x F_3) and (clay x F_4), showed highest mean values for the average tuber weight character. The data of the interaction trimming treatments x fertilization treatments (Table, 3) showed that the interaction (T_0 x F_3) and (T_0 x F_4) significantly gave the highest mean values for number of tubers / plant and tubers' yield / feddan traits during the two seasons. The data of the first season appeared that the interactions included the un-trimming treatment significantly gave highest mean values for the average tuber weight compared with the interactions included trimming treatment (Table, 3). As for the second season, the obtained data showed that the interaction (T_1 x F_2) possessed the highest mean value for the average tuber weight character without significant differences with the interactions (T_1 x F_1), (T_1 x F_3), (T_0 x F_4), (T_0 x F_1), (T_0 x F_3) and (T_0 x F_4). The data of the interaction soil types x trimming treatments x fertilization treatments showed significant differences for tuber yield / feddan and the studied component characters (number of tubers / plant and average tuber weight) during the two seasons (Table, 3). As for number of tubers / plant character, the results of the two seasons showed that the interactions (clay x T_0 x F_3) and (clay x T_0 x F_4) possessed the highest mean values in this respect. Similar results were also obtained regarding the average tuber weight character during the first season, where, the two interactions (clay x T_0 x F_3) and (clay x T_0 x F_4) significantly gave the highest mean values. The results of the second season showed that the interaction (clay x T_1 x F_4) gave the highest mean value without significant differences with the interactions (calcareous x T_1x F_2), (clay x T_1 x F_1), (clay x T_1 x F_3), (clay x T_0 x F_1) and (clay x T_0 x F_3). As shown from Table (3), the data of tubers' yield / feddan showed that the two interactions (clay x T_0 x F_3) and (clay x T_0 x F_4) possessed the highest mean values during the two seasons of this study. It was clear from Table (3) that the maturity trait was not significantly affected by any of the studied interactions during the two study seasons. Generally, it was observed through the previous results especially for tubers' yield / feddan and number of tubers / plant traits

Table 3. Mean performances of tubers' yield and its component characters of Jerusalem artichoke plants during the seasons of 2016 and 2017

Treatments			No. of tubers/plant	No. of tubers/plant	Average tuber weight (g)	Average tuber weight (g)	Tubers' yield (ton/Fed.)	Tubers' yield (ton/Fed.)	Maturity (days)	Maturity (days)
Soil type	Trimming	Fertilization treatments	Seasons							
			2016	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
Calcareous			135.13b*	113.17b	57.23a	49.06b	30.97b	22.10b	243.83a	243.79a
Clay			157.50a	138.08a	57.74a	51.21a	36.40a	28.27a	243.87a	243.83a
	T_1		141.79b	118.38b	55.94b	50.48a	31.73b	23.88b	243.71a	243.63a
	T_0		150.83a	132.88a	59.04a	49.79a	35.63a	26.48a	244.00a	244.00a
		F_1	143.67b	121.67b	57.58ab	50.68a	33.10b	24.67b	244.00a	244.00a
		F_2	141.00b	116.67c	56.79b	49.96a	32.10c	23.13c	244.00a	244.00a
		F_3	149.92a	131.08a	57.88a	49.93a	34.73a	26.27a	243.67a	243.67a
		F_4	150.67a	133.08a	57.69a	49.96a	34.80a	26.67a	243.75a	243.58a
Calcareous	T_1		130.67d	104.08d	55.78b	48.92b	29.16d	20.01d	243.67a	243.58a
	T_0		139.58c	122.25c	58.68a	49.21b	32.76c	24.08c	244.00a	244.00a
Clay	T_1		152.92b	132.67b	56.09b	52.04a	34.32b	27.64b	243.75a	243.67a
	T_0		162.08a	143.50a	59.39a	50.38ab	38.52a	28.92a	244.00a	244.00a
Calcareous		F_1	131.17e	108.33e	57.66a	50.00abc	30.28d	21.60e	244.00a	244.00a
		F_2	129.83e	100.17f	55.78b	51.09ab	29.00e	20.28f	244.00a	244.00a
		F_3	139.00d	120.17d	57.88a	47.76c	32.20c	23.00d	243.67a	243.67a
		F_4	140.50d	124.00c	57.62a	47.40c	32.40c	23.52d	243.67a	243.50a
Clay		F_1	156.17b	135.00b	57.50a	51.37ab	35.92b	27.72b	244.00a	244.00a
		F_2	152.17c	133.17b	57.80a	48.84bc	35.20b	26.00c	244.00a	244.00a
		F_3	160.83a	142.00a	57.88a	52.10a	37.28a	31.32a	243.67a	243.67a
		F_4	160.83a	142.17a	57.76a	52.52a	37.20a	29.92a	243.83a	243.67a
	T_1	F_1	139.00d	114.50c	56.62b	50.98ab	31.48d	23.32d	244.00a	244.00a
		F_2	137.83d	105.50d	54.31c	51.44a	30.00e	21.48e	244.00a	244.00a
		F_3	144.83bc	125.17b	56.65b	49.50ab	32.80c	24.92c	243.33a	243.33a
		F_4	145.50bc	128.33b	56.17b	49.98ab	32.68c	25.80b	243.50a	243.17a
	T_0	F_1	148.33b	128.83b	58.54a	50.38ab	34.72b	26.00b	244.00a	244.00a
		F_2	144.17c	127.83b	59.27a	48.49b	34.20b	24.80c	244.00a	244.00a
		F_3	155.00a	137.00a	59.12a	50.036ab	36.68a	27.60a	244.00a	244.00a
		F_4	155.83a	137.83a	59.21a	49.94ab	36.92a	27.52a	244.00a	244.00a

Cont. Table 3.

Treatments			No. of tubers/plant	No. of tubers/plant	Average tuber weight (g)	Average tuber weight (g)	Tubers' yield (ton/Fed.)	Tubers' yield (ton/Fed.)	Maturity (days)	Maturity (days)
Soil type	Trimming	Fertilization treatments								
			Seasons							
			2016	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
Calcareous	T_1	F_1	126.33h	98.00g	56.74c	50.80bcd	28.68h	19.88h	244.00a	244.00a
		F_2	126.67h	84.33h	52.91d	53.89ab	26.80i	18.12i	244.00a	244.00a
		F_3	134.00g	113.00f	56.97bc	46.05ef	30.52g	20.80gh	243.33a	243.33a
		F_4	135.67g	121.00e	56.51c	44.92f	30.68g	21.72fg	243.33a	243.00a
Calcareous	T_0	F_1	136.00g	118.67e	58.58ab	49.19cde	31.88f	23.32e	244.00a	244.00a
		F_2	133.00g	116.00ef	58.65ab	48.29def	31.20fg	22.40ef	244.00a	244.00a
		F_3	144.00f	127.33d	58.79a	49.47cde	33.88de	25.20d	244.00a	244.00a
		F_4	145.33f	127.00d	58.72a	49.89cde	34.12cde	25.32d	244.00a	244.00a
Clay	T_1	F_1	151.67de	131.00cd	56.50c	51.16abcd	34.28cde	38.8c	244.00a	244.00a
		F_2	149.00ef	126.67d	55.71c	48.99de	33.20e	24.80d	244.00a	244.00a
		F_3	155.67cd	137.33b	56.32c	52.94abc	35.08c	29.08ab	243.33a	243.33a
		F_4	155.33cd	135.67bc	55.82c	55.04a	34.68cd	29.88a	243.67a	243.33a
Clay	T_0	F_1	160.67bc	139.00b	58.51ab	51.58abcd	37.60b	28.68b	244.00a	244.00a
		F_2	155.33cd	139.67b	59.89a	48.69def	37.20b	27.20c	244.00a	244.00a
		F_3	166.00ab	146.67a	59.44a	51.25abcd	39.48a	30.00a	244.00a	244.00a
		F_4	166.33a	148.67a	59.71a	50.00bcd	39.72a	29.72ab	244.00a	244.00a

* Values marked with the same alphabetical letter (s), within a comparable group of means, are not significantly different, using L.S.D. test at P=0.05 level.

that most of the interactions had trimming process gave negative results compared to the interactions had un-trimming process. These negative results of the trimming treatment on the tubers' yield productivity might be due doing trimming process lately at the end of the vegetative growth stage and beginning the initiation of the flowering stage, which the plants become old and woody. In this context, topping did not positively effect on cotton yield, and was less effective when applied later in the season (Naguib *et al*., 1987).

Tubers' quality

Effects of soil types on tubers' quality characters

As shown from Table (4), all the studied tubers' quality characters significantly affected with soil type differences. The highest mean values were scored when Jerusalem artichoke plants grown under clay soil conditions.

Effects of trimming treatments on tubers' quality characters

The data of Table (4) showed that un-trimming treatment significantly gave the highest mean values for the quality characteristics; i.e., tubers' dry weight %, inulin and starch percentages during the two seasons.

Effects of fertilization treatments on tubers' quality characters

Tubers' dry weight percentage seemed to be affected with the applied fertilization treatments (Table, 4). Fertilization treatment F_4 significantly gave the highest mean values for Tubers' dry weight percentage followed with the fertilization treatment F_3 across the two seasons. Same trend of results were detected for inulin percentages; where the fertilization treatments F_4 significantly gave the highest mean values followed with the fertilization treatment F_3. As for starch percentage; the obtained data appeared that each of the two fertilization treatments F_3 and F_4 significantly possessed the highest mean values during the two seasons. The results of Tony (2013) showed that use combining bio-fertilizer and chemical fertilization led to increase of dry weight by 18.1% when compared to control. Ghoneim (2005) emphasized that inoculation of seed pieces of globe artichoke either with Halex-2 significantly recorded the higher mean values for dry weight and total carbohydrates than those of the un-inoculated control. The obtained results agreed, in general, with those of Sorial *et al*. (1998), who reported some enhancing effects on dry weight content as a result of inoculation with a bio-fertilizer.

Effects of interactions on tubers' quality characters

The data of Table (4) generally appeared that the interactions soil types x trimming treatments were significant for all the studied quality characters during the two seasons. In this respect, the results showed that the interaction (clay x T_0) was significantly superior to the other interactions for all the studied quality traits over the two seasons. Same approach of results were also detected for the interaction soil types x fertilization treatments; where all tested quality traits exhibited significant effects for such interaction across the two seasons. The interaction (clay x F_4) possessed the highest mean values for all the quality characters without significant differences with the interaction (clay x F_3) for dry weight and starch percentages (Table, 4). All of the tested quality characters significantly affected with the interaction trimming treatments x fertilization treatments; as shown in Table (4). The data of the dry weight percentage showed that the interaction (T_0 x F_4) gave the highest mean values during the two seasons. There were no significant differences between the interaction (T_0 x T_3) and (T_0 x F_4) during the two seasons. It appears from Table (4) that the interaction (T_0 x F_4) significantly gave the highest mean values for the inulin percentage across the two seasons. As for starch percentage, the data of Table (4) showed that the interaction (T_0 x F_4) possessed the highest mean value without significant differences with the interactions (T_0 x T_1) and (T_0 x T_3) during the first season. The results of the second season appeared that the two interactions (T_0 x T_3) and (T_0 x F_4) significantly gave the highest mean values for starch percentage. The data of Table (4) showed that most of the desired results for the quality characteristics have been achieved through the interactions (clay x T_0 x F_3) and (clay x T_0 x F_4) especially for tuber dry weight and starch percentages across the two seasons. As detected from the tested interactions (Table, 4) it is promising to use bio-stimulants Halex-2 plus yeast extract with a moderate supply level of nitrogen fertilizer (75 kg N fed/Fed.) in order to improve Jerusalem artichoke tubers quality characteristics whether the cultivation in clay or calcareous soils. The results of Ezzat *et al*., (2013) on Jerusalem artichoke plants confirmed that tubers' dry weight and inulin percentages increased with increasing nitrogen rate up to 90 kg/Fed. In this respect, Sawicka (2002) found that inulin content was the highest in object with adding nitrogen up to 50 kg ha^{-1}; while tubers' dry weight content increased up to 100 kg nitrogen ha^{-1}.

Table 4. Mean performances of tubers' quality characters of Jerusalem artichoke plants during the seasons of 2016 and 2017

Treatments			Tubers' dry weight (%)	Tubers' dry weight (%)	Inulin (%)	Inulin (%)	Starch (%)	Starch (%)
Soil type	Trimming	Fertilization treatments						
			Seasons					
			2016	2017	2016	2017	2016	2017
Calcareous			20.82b*	20.35b	13.45b	14.58b	23.54b	22.10b
Clay			22.96a	23.75a	14.94a	15.75a	25.62a	25.36a
	T_1		20.71b	21.29b	13.40b	14.03b	24.09b	22.88b
	T_0		23.07a	22.81a	14.98a	16.30a	25.07a	24.59a
		F_1	21.57c	21.86c	14.08c	14.95c	24.40b	23.65b
		F_2	20.38d	20.96d	13.44d	14.17d	23.73c	22.88c
		F_3	22.41b	22.49b	14.42b	15.46b	25.05a	24.20a
		F_4	23.19a	22.90a	14.83a	16.08a	25.14a	24.22a
Calcareous	T_1		19.53c	19.16d	12.63c	13.33d	23.19d	21.09d
	T_0		22.09b	21.54c	14.27b	15.83b	23.89c	23.12c
Clay	T_1		21.87b	23.42b	14.18b	14.73c	24.98b	24.66b
	T_0		24.04a	24.08a	15.70a	16.78a	26.25a	26.07a
Calcareous		F_1	20.69e	19.91f	13.37g	14.40e	23.25e	22.22e
		F_2	19.05f	18.86g	12.68h	13.53f	22.80e	21.17f
		F_3	21.35de	21.00e	13.73f	14.85d	23.91d	22.60d
		F_4	22.17bc	21.63d	14.02e	15.53c	24.2cd	22.43de
Clay		F_1	22.46b	23.80b	14.78c	15.50c	25.55b	25.09b
		F_2	21.70cd	23.06c	14.20d	14.80d	24.65c	24.58c
		F_3	23.47a	23.97ab	15.12b	16.07b	26.20a	25.79a
		F_4	24.20a	24.16a	15.65a	16.63a	26.07ab	26.00a
	T_1	F_1	20.19f	21.04e	13.35g	13.67f	23.83d	22.90e
		F_2	19.17g	19.96f	12.58h	12.90g	23.13e	21.98f
		F_3	21.18e	21.96d	13.68f	14.45e	24.66bc	23.36d
		F_4	22.29cd	22.20d	14.00e	15.10d	24.73bc	23.27de
	T_0	F_1	22.96bc	22.67c	14.80c	16.23b	24.97ab	24.40b
		F_2	21.58de	21.95d	14.30d	15.43c	24.32cd	23.77c
		F_3	23.64ab	23.02b	15.17b	16.47b	25.45a	25.03a
		F_4	24.09a	23.60a	15.67a	17.07a	25.55a	25.17a
Calcareous	T_1	F_1	19.44g	18.57i	12.70h	13.00g	22.80gh	21.40h
		F_2	17.83h	17.27j	11.80i	12.20h	22.30h	20.03i
		F_3	20.03fg	20.22h	12.93gh	13.70f	23.64efg	21.63h
		F_4	20.85f	20.57h	13.10g	14.43e	24.03def	21.30h
Calcareous	T_0	F_1	21.94de	21.26g	14.03e	15.80c	23.70ef	23.03f
		F_2	20.27fg	20.45h	13.57f	14.87d	23.30fg	22.30g
		F_3	22.68cd	21.78f	14.53d	16.00c	24.17def	23.57ef
		F_4	23.49bc	22.69e	14.93c	16.63b	24.40de	23.57ef
Clay	T_1	F_1	20.93ef	23.50d	14.00e	14.33e	24.78cd	24.40d
		F_2	20.50f	22.66e	13.37f	13.60f	23.97ef	23.93de
		F_3	22.33d	23.70cd	14.43d	15.20d	26.67bc	25.08c

Cont. Table 4.

Treatments			Tubers' dry weight (%)	Tubers' dry weight (%)	Inulin (%)	Inulin (%)	Starch (%)	Starch (%)
Soil type	Trimming	Fertilization treatments						
			Seasons					
			2016	2017	2016	2017	2016	2017
		F_4	23.72abc	23.82bcd	14.90c	15.77c	25.43bc	25.23bc
Clay	T_0	F_1	23.98ab	24.09abc	15.57b	16.67b	26.23ab	25.77b
		F_2	22.90cd	23.46d	15.03c	16.00c	25.33c	25.33bc
		F_3	24.61a	24.25ab	15.80b	16.93b	26.73a	26.50a
		F_4	24.68a	24.50a	16.40a	17.50a	26.70a	26.77a

* Values marked with the same alphabetical letter (s), within a comparable group of means, are not significantly different, using L.S.D. test at P=0.05 level.

N, P and K in tubers

Effects of soil types on N, P and K

As for the tested main elements, the data of Table (5) showed that soil types showed significant effects on the tested main elements (N, P and K) during the two seasons; where clay soil possessed the highest mean values in this respect. These significance differences in the content of the tubers from the available main mineral elements (N, P and K) can be attributed to the estimated fundamental differences of these elements in the two soil types (Table, 1).

Effects of trimming treatments on N, P and K

With regard to the applied trimming treatments, it was clear from the results in Table (5) that un-trimming treatment had positive effects on the content of the tubers from the three mineral elements (N, P and K) during the two seasons.

Effects of fertilization treatments on N, P and K

The data of nitrogen content showed that the fertilization treatments F_3 and F_4 significantly gave the highest mean values for nitrogen content during the two seasons (Table, 5). Fertilization treatment F_2 significantly gave the best results for phosphorus content over the two seasons. This result can be attributed to the role of yeast extract in its positive effect on the growth and spread of plant roots, making it more absorbable for phosphorus from the soil. The fertilization treatment F_4 significantly gave the highest mean value for tubers' potassium content during the two experimental seasons followed with the fertilization treatments F_1 and F_3 (Table, 5). The result of Abdel-Razzak and El-Sharkawy (2013) reflected that inoculated garlic cloves with bio-fertilizer (Halex-2) increased K concentration in garlic tissues compared with un-inoculated plants. However, the authors illustrated that concentrations of N and P did not reflect any differences.

Effects of interactions on N, P and K

As shown from the Table (5), all studied interactions exhibited significant effects for the studied main element contents (N and K) during the two seasons. It appears from Table (5) that tubers' phosphorus content did not affect with such interactions. The results presented in Table (5) for the interaction soil types x trimming treatments indicated that growing Jerusalem artichoke plants in clay soil without trimming significantly increased both N and K concentrations in tubers. This result might be owing to that, the un-trimming treatment possessed better results for the vegetative growth parameters, tubers' yield and its component characters, which positively reflected the content of the tubers from the estimated N and K mineral elements (Tables 2 and 3). The results obtained from Table (5); generally showed the superiority of the clay soil in their interaction with the fertilization treatments compared with the calcareous in relation to the estimated mineral elements. As for nitrogen content, the data showed that the interaction clay x F_1 and clay x F_3 significantly gave the highest mean values during the first season; while in the second season, both clay x F_3 and clay x F_4 superiority over the rest of the interactions. The interaction clay x F_4 significantly gave the highest mean values for tubers content of potassium during the two season of the experimentation. The solubility of nutrients is particularly low and the nutrients deficiencies were often shown on the plants grown on calcareous soils because of high pH (Kacar and Katkat, 2007). The obtained results could be returned that the growing plants take more mineral elements due to the better-developed root systems when planting in clay soil. For the interaction between the trimming treatments and the fertilization treatments, the results of Table (5) showed superiority of the interactions un-trimming x F_3 and un-trimming x F_4 regarding nitrogen and potassium contents, respectively during the two seasons. Tubers significantly contained highest mean values of nitrogen through the interactions clay x T_0 x F_1 and clay x T_0 x F_3 during the first season; while the interactions clay x T_0 x F_3 and clay x T_0 x F_4 gave the highest mean values for nitrogen content during the second season (Table, 5). Potassium content results showed superior the interactions clay x T_0 x F_1 and clay x T_0 x F_4 on the rest of the tested interactions during the first season. On the other hand, the interaction clay x T_0 x F_4 gave the highest mean value for potassium content during the second season. Generally, In general, the results showed an increase in potassium content through the treatment 100 kg nitrogen/feddan followed by the treatments containing a mixture of both halex-2 and yeast extract. As for the results of tubers content of phosphorus, the results shown in Table (5) showed the absence of the significant of all studied interactions, although there were clear differences between the treatments within each interaction. This can be attributed to the fact that the results of each of these interactions are in a harmonious direction during the two study seasons. In this respect, phosphorus contents were increased when Jerusalem artichoke plants were grown in clay soil without trimming. Also, phosphorus contents were increased when the plants were grown in clay soil with any of the applied fertilization treatments. In the same context, the superiority of the phosphorus results was shown in the case of non-trimming of the growing plants with any of the fertilization treatments compared to trimming treatment. The results of Ezzat *et al*., (2013) on Jerusalem artichoke plants showed that increasing nitrogen fertilizers up to 90 kg/Fed. led to increasing in macro and micronutrients. Finally, it was evident from the results that phosphorus contents were increased when the tubers were planted in clay soil without trimming the growing plants with any of the applied fertilization treatments during the two seasons of the experiment.

Table 5. Mean performances of tubers' N, P and K characters of Jerusalem artichoke plants during the seasons of 2016 and 2017

Treatments			Nitrogen (%)	Nitrogen (%)	Phosphorus (%)	Phosphorus (%)	Potassium (%)	Potassium (%)
Soil type	Trimming	Fertilization treatments						
			Seasons					
			2016	2017	2016	2017	2016	2017
Calcareous			2.22 b*	2.05 b	0.32 b	0.24 b	2.37 b	2.12 b
Clay			3.02 a	2.87 a	0.52 a	0.42 a	5.05 a	4.74 a
	T_1		2.51 b	2.30 b	0.36 b	0.29 b	3.45 b	3.18 b
	T_0		2.74 a	2.61 a	0.47 a	0.37 a	3.97 a	3.68 a
		F_1	2.68 b	2.48 b	0.38 c	0.30 c	3.67 b	3. 36 b
		F_2	2.25 c	2.06 c	0.46 a	0.37 a	3.39 c	3.06 c
		F_3	2.83 a	2.64 a	0.44 b	0.35 b	3.57 b	3.32 b
		F_4	2.71 ab	2.65 a	0.39 c	0.30 c	4.22 a	3.99 a
Calcareous	T_1		2.14 d	1.96 d	0.27 a	0.23 a	2.28 d	2.08 c
	T_0		2.30 c	2.14 c	0.36 a	0.26 a	2.46 c	2.16 c
Clay	T_1		2.88 b	2.65 b	0.44 a	0.35 a	4.62 b	4.28 b
	T_0		3.17 a	3.09 a	0.59 a	0.48 a	5.49 a	5.21 a
Calcareous		F_1	2.25 e	2.08 e	0.28 a	0.22 a	2.25 e	2.03 e
		F_2	1.68 f	1.47 f	0.35 a	0.28 a	2.02 f	1.68 f
		F_3	2.50 d	2.33 d	0.34 a	0.26 a	2.15 ef	1.92 e
		F_4	2.45 d	2.32 d	0.29 a	0.22 a	3.05 d	2.85 d
Clay		F_1	3.12 ab	2.88 b	0.49 a	0.39 a	5.09 b	4.68 b
		F_2	2.83 c	2.66 c	0.57 a	0.46 a	4.76 c	4.43 c
		F_3	3.17 a	2.95 ab	0.54 a	0.44 a	4.98 b	4.73 b
		F_4	2.99 bc	2.99 a	0.48 a	0.38 a	5.38 a	5.12 a
	T_1	F_1	2.58 c	2.40 c	0.32 a	0.26 a	3.39 e	3.12 e
		F_2	2.15 e	1.93 e	0.41 a	0.32 a	3.07 f	2.78 f

Cont. Table 5.

Treatments			Nitrogen (%)	Nitrogen (%)	Phosphoru s (%)	Phosphoru s (%)	Potassium (%)	Potassium (%)
Soil type	Trimming	Fertilization treatments						
			Seasons					
			2016	2017	2016	2017	2016	2017
		F_3	2.66 bc	2.45 c	0.37 a	0.30 a	3.33 e	3.04 e
		F_4	2.65 bc	2.44 c	0.34 a	0.27 a	4.00 b	3.78 b
	T_0	F_1	2.79 b	2.56 b	0.45 a	0.34 a	3.95 bc	3.60 c
		F_2	2.36 d	2.20 d	0.52 a	0.42 a	3.71 d	3.33 d
		F_3	3.0 a	2.83 a	0.50 a	0.39 a	3.80 cd	3.60 c
		F_4	2.80 b	2.86 a	0.43 a	0.32 a	4.43 a	4.20 a
Calcareous	T_1	F_1	2.21 e	2.10 f	0.23 a	0.19 a	2.17 g	2.07 g
		F_2	1.63 f	1.41 g	0.31 a	0.26 a	1.80 h	1.63 i
		F_3	2.36 de	2.17 f	0.30 a	0.25 a	2.13 g	1.83 hi
		F_4	2.34 de	2.15 f	0.26 a	0.22 a	3.00 f	2.80 f
Calcareous	T_0	F_1	2.30 e	2.06 f	0.34 a	0.24 a	2.33 g	2.00 gh
		F_2	1.72 f	1.52 g	0.39 a	0.31 a	2.24 g	1.73 i
		F_3	2.63 c	2.48 e	0.37 a	0.27 a	2.17 g	2.00 gh
		F_4	2.57 cd	2.49 e	0.33 a	0.23 a	3.10 f	2.90 f
Clay	T_1	F_1	2.95 b	2.69 d	0.42 a	0.33 a	4.60 e	4.17 d
		F_2	2.66 c	2.45 e	0.50 a	0.39 a	4.35 e	3.93 e
		F_3	2.96 b	2.72 d	0.45 a	0.35 a	4.52 e	4.25 d
		F_4	2.95 b	2.74 d	0.42 a	0.33 a	5.00 d	4.77 c
Clay	T_0	F_1	3.28 a	3.07 b	0.55 a	0.45 a	5.57 ab	5.20 b
		F_2	3.00 b	2.87 c	0.64 a	0.53 a	5.17 cd	4.93 c
		F_3	3.37 a	3.18 ab	0.63 a	0.52 a	5.44 bc	5.20 b
		F_4	3.02 b	3.23 a	0.54 a	0.42 a	5.76 a	5.49 a

* Values marked with the same alphabetical letter (s), within a comparable group of means, are not significantly different, using L.S.D. test at P=0.05 level.

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الملخص العربي

دراسة فسيولوچية على نباتات الطرطوفة المنزرعة فى نوعين من التربة

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أجريت تجربتين حقليتين على محصول الطرطوفة خلال موسمين متتاليين هما ٢٠١٦ ، ٢٠١٧ بمعمل بحوث الأراضى الملحية والقلوية ، مركز البحوث الزراعية ، محافظة الإسكندرية ، مصر. إشتملت كل تجربة على عدد ١٦ معاملة تمثل التداخل بين العوامل الآتية : نوعان من التربة (طينية ،و جيرية) ، معاملتان من التشذيب (إزالة البراعم الزهرية قبل تفتحها مع جزء يقدر ب ١٠ – ٢٠ سم من نهايات الافرع الخضرية ، بدون تشذيب) ، أربعة إضافات من معاملات التسميد وهى (٧٥ كجم نيتروجين / فدان + هالكس ٢ ، ٧٥ كجم نيتروجين / فدان + مستخلص الخميرة ، ٧٥ كجم نيتروجين / فدان + هالكس ٢ + مستخلص الخميرة ، ١٠٠ كجم نيتروجين / فدان). نفذت التجربة وتم إجراء التحليل الإحصائى بنظام القطع المنشقة المنشقة بتصميم القطاعات الكاملة العشوائية ذو ثلاث مكررات . مثل نوع التربة القطع الرئيسية ، بينما مثلت معاملات التشذيب القطع المنشقة ، فى حين مثلت معاملات التسميد القطع المنشقة المنشقة حيث وزعت معاملات التسميد عليها بطريقة عشوائية .

أهم النتائج المتحصل عليها :

١–زراعة درنات الطرطوفة فى الأرض الطمية أدى الى زيادة النمو الخضرى والمحصول الدرنى ومكوناته مقارنة بالزراعة فى الأرض الجيرية .

٢–كان لعدم تشذيب نهايات الأفرع الخضرية لنباتات الطرطوفة تأثيرات إيجابية على كل من النمو الخضرى ، والمحصول الدرنى ، ومكوناته مقارنة بعملية التشذيب .

٣–إضافة ٧٥ كجم نيتروجين / فدان الى جانب الهالكس ٢ + مستخلص الخميرة أدى الى الحصول على نتائج متساوية إحصائيا مع المعاملة ١٠٠ كجم نيتروجين / فدان وذلك للصفات الخضرية المدروسة ، والمحصول الدرنى ، ومكوناته .

٤–لم تتأثر صفة ميعاد النضج بأى من المعاملات المطبقة على نباتات الطرطوفة النامية .

٥–تبين من النتائج أنه يمكن تقليل ربع كمية الأسمدة النيتروجينية المعدنية المضافة الى التربة وتعويض النقص من خلال إضافة خليط من المحفزات الحيوية (هالكس ٢ + مستخلص الخميرة) إلى النباتات النامية إضافة إلى عدم تشذيب نهايات الأفرع الخضرية سواء أكانت الزراعة في التربة الطينية أو الجيرية.