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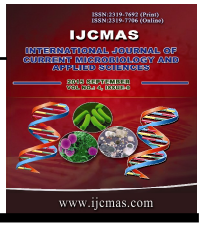

Original Research Article

Improving Growth and Yield of Caraway (*Carum carvi* L.,) Plants by Decapitation and/or Active Dry Yeast Application

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Keywords

Caraway, Decapitation, Yeast, Growth, Yield, Anatomy

A B S T R A C T

The present study was conducted during two successive seasons of 2011/2012 and 2012/2013 to overcome apical dominance in a main shoot in an intact caraway plant and to promoting outgrowth of axillary buds. Both intact and decapitated caraway plants were sprayed with tap water as the control and/or 1 and 2g/l of active dry yeast. The results showed that decapitation process alone and/or with active dry yeast application resulted in increasing growth characters (Plant height, Number of branches/plant), chemical constituents (N, P, K, Ca, Mg, Fe, Zn and Mn % in shoot and root), total carbohydrates %, oil and also, increased yield characters of caraway plant represented in Number of umbles/plant, Number of umblet/ umbles, yield /plant (g), yield/ha (ton), Yield of oil (kgha^{-1}) and oil (%). Anatomical measurements were also increased and those were reflected on yield potential.

Introduction

Caraway (*Carum carvi* L.) plant belongs to family Apiaceae, and it's considered among the most important plants containing volatile oils. It is a biennial herbaceous plant native to Wastern Asia, Europe and Northern Africa. Its height ranging from 1-1.2m with little lateral branches under normal conditions, perhaps it has apical dominance phenomenon with subsequent repression of lateral buds outgrowth. The fruits of caraway plant and its essential oil have several medicinal purposes, i.e. as carminative, mild stomachic and antispasmodic, as a tonic in the treatment of digestive disorders. Dried fruits are widely employed for flavoring bread, cake confectionery, cheese and kinds of feed products (Mohamed, 2007). There are numerous techniques to improve the growth and yield of caraway plant, including overcoming the problem of apical dominance then encourage shoot branching through the process of decapitation, which in turn leads to improved growth and production.

Decapitation is an ethno-agriculture practice, often carried out by farmers to increase the yield potentials of many crops. Udeogalanya and Muoneke (1985) as well as Udengwu (2009), reported that the effects of ethno-agricultureal practice on the production of marketable fresh fruits of okra.

The phenomenon of the apical dominance is characterized by growing of main stem and repress of axillary branch growth currently the polar auxin transport in main shoot is maintained. After removal of shoot apex, the dormant lateral buds are released from growth inhibition and their outgrowth is initiated (Cline 1991, 1996; Shimizu-Sato and Mori, 2001; Daňková and Reinöhl, 2013). Axillary buds also derive from the primary SAM in a developmental process that generally involves two phases. (1) The axillary meristem is formed from groups of meristematic cells, which originate directly from detached parts of the primary SAM of the main shoot. The axillary meristem produces axillary buds located on the axil of the leaf primordia. (2) After axillary buds are fully developed and have reached a certain size depending on the plant species, growth ceases and the axillary bud becomes dormant (Shimizu-Sato *et al.*, 2009).

Active dry yeast (ADY) is a natural safety biofertilizers causes various promotive effects on plants. It contains major and minor nutrients, amino acids, vitamins and growth promoting substances such as cytokinins which simulate cell division and enlargement.

Recently, the use of natural ADY as bio-stimulants which has been an important but largely unfulfilled aim of modern agricultural development (Gaballah and Gomaa, 2004), has allowed for partial substitution of conventional synthetic fertilizer. Bio-stimulants can be generally defined as plant growth regulator or promoting substances such as vitamins, microelements, organic acids.

The objective of the present study is to improve the growth and yield of caraway plants by decapitation and/or active dry yeast application and consequently increasing yield potential of caraway plant.

Material and Methods

Plant material, growth conditions, experimental design and treatments

Two field experiments were carried out during two successive seasons of 2011/2012 and 2012/2013, at the Dar El Ramad Experimental Farm of the Faculty of Agriculture, Fayoum University, Southeast Fayoum (29° 17′N; 30° 53′E), Egypt. In both seasons, the daily temperatures averaged 20.3° ± 2.5 °C and 21.5 ± 2.6 °C, and the daily relative humidity averaged 58.4 ± 5.1% and 60 ± 4.9%, during the first and second seasons, respectively.

Healthy seeds of caraway (*Carum carvi* L.) were obtained from Agricultural Research Center, Ministry of Agriculture and Land reclamation, Giza, Egypt. Seeds were selected for vital by choosing those of equal size and of the same color, and then were washed with distilled water, sterilized in 1% (v/v) sodium hypochlorite for approx. 2 min, washed thoroughly again with distilled water. Seeds were left to dry at room temperature overnight, and air-dried. Caraway seeds were sown on 15 October 2011, and on 18 October 2012, in hills spaced 20–25 cm apart, in rows spaced 70 cm apart in 3.0 m × 3.5 m plots. Two plants per hill were remained after thinning was done before the first irrigation. During the soil preparation and plant growth, the soil was supplemented with the full dose of NPK fertilizer according to the recommendations of the Ministry of Agriculture and Land Reclamation. These recommendations were for 480 kg ha^{-1} calcium superphosphate (15.5% P_2O_5), was added during seed-bed preparation, 480 kg ha^{-1} ammonium sulfate (20.5% N), and 120 kg ha^{-1} potassium sulfate (48% K_2O) were added during growth. Irrigation water was added to 100%

of the reference crop evapotranspiration (ETo), values from the Fayoum Meteo Station. All other recommended agricultural practices were followed as recommended by the Ministry of Agriculture and Land Reclamation.

An experimental site was the same during the two successive seasons. Soil analyses were carried out according to Klute (1986) and Page *et al.* (1982). The soil texture was clay [fine sand (%, w/v), 19.19 and 18.5; coarse sand (%, w/v), 4.70 and 5.00; silt (%, w/v), 20.0 and 21; clay (% w/v), 56.11 and 55.0 in both seasons, respectively]. The other main characteristics of the soil in the two growing seasons were: pH [at a soil:water (w/v) ratio of 1:2.5], 1.90 and 2.50; EC (dS m^{-1}; soil–paste extract), 5.35 and 5.45; organic matter [% (w/v)], 0.94 and 0.92; $CaCO_3$[% (w/v)], 8.96 and 7.89; total N [% (w/v)], 70 and 71; available P (mg kg^{-1} soil), 17 and 17.5; available K (mg kg^{-1} soil), 420 and425; available Fe (mg kg^{-1} soil), 10.52 and 12.75; available Mn (mg kg^{-1} soil), 6.15 and 4.88; available Zn (mg kg^{-1} soil), 2.60 and 2.75; and available Cu (mg kg^{-1} soil), 0.80 and 0.90, respectively. The experiments were arranged in a randomized complete block design, with three levels of active dry yeast (0, 1 and 2 g/l), with three replicate plots.

Forty days after sowing (DAS), caraway seedlings were decapitated (approximately 0.5 cm above the first node was removed).Both decapitated and intact seedlings were sprayed immediately after the decapitation to turn off with tap water as the control and by active dry yeast at the rate of 1 and 2 g/l., as treated seedlings. To ensure optimal penetration into leaf tissue, tween 20 was added to the foliar sprays as surfactant (0.1 % v/v). All caraway seedlings were twice sprayed at 40 and 60 DAS. The experimental treatments were intact seedlings as control, decapitated (Dec.), Intact+1g/l ADY, Intact+2g/lADY, Dec.+1g/lADY and Dec., +2g/l ADY.

Plant growth and yield analyses

Ninty-day-old caraway plants (n = 9) were carefully removed from each experimental plot and washed with water to remove all adhering soil particles. Plant heights were measured, from the cotyledonary node to the terminal bud of the main stem, using a meter scale. Number of branches was counted per plant. At the harvest date (20^{th}June 2012 and 25^{th} June 2013), all plants in each experimental plot were harvested and then count number of umbels/plant, number of umblet/umbles. The dry fruits of caraway were extracted from the inflourences and weighted, then the seed yield/plant, and fruits yield/hectare were calculated.

Anatomical Study

Samples for anatomical study were taken during the first season at the age 90 days after sowing. Specimens (0.5 cm in length) from the middle part of the main root and the middle part of the 5^{th} internode were killed and fixed in an FAA solution (10 ml formalin + 5 ml glacial acetic acid + 50 ml ethylalcohol 95% + 35 ml distilled water) for 72 hours. Thereafter, samples were washed in 50% ethyl alcohol, dehydrated, cleared in n-butyl alcohol series and embedded in paraffin wax of 56–58 °C m.p. Cross sections of 20µ thick were cut, using a rotary microtom, adhered to slides by Haupt's adhesive. Slides were then stained with the Crystal violet–erythrosin combination, cleared in carbol xylene and mounted in Canada balsam. Slides were microscopically analyzed and sections were microphotographed. An average of five readings was calculated by using a micrometer eyepiece (Nassar and El-Sahhar,

1998).

Determination of chemicals

Samples of roots and shoots were dried in an oven at 70 °C till constant weight then ground for the following determinations:

Total carbohydrates %

Total carbohydrates% was determined according to the method of Dubois *et al.* (1956). Root and shoot samples (0.1 g; n = 9) were hydrolyzing with $0.1H_2SO_4$for 20 minutes in water bath at 100 °C. After cooling the solution, traces of barium carbonate were added for protein precipitation then the solution was filtered into 100 ml measuring flasks and completed to mark with distilled water. The absorbance was recorded at 480 nm with a Bausch and Lomb-2000 Spectronic Spectrophotometer.

Determination of elements (Macro and micronutrients)

Percentage of Nitrogen, phosphorus, calcium, iron, manganese and zinc in shoots and roots were determined using a Perkin-Elmer Model 3300 Atomic Absorption Spectrophotometer (Chapman and Pratt, 1961) after digesting the plant material in a mixture of concentrated sulfuric acid and perchloric acids. K^+ ion contents (in mg g^{-1} DW) were assessed using a Perkin-Elmer Model 52-A Flame Photometer (Glenbrook, Stamford, CT, USA; Page *et al.*, 1982).

Volatile oil:

The volatile oil % and yield in air dry fruits were determined by water steam distillation according to the British pharmacopeia methods (Anonym 1968).

Statistical analysis

All data were subjected to analysis of variance (ANOVA) for a randomized complete block design, after testing for homogeneity of error variances according to the procedure outlined by Gomez and Gomez and Gomez (1984). Combined analysis of data for the two seasons was conducted and significant differences between treatments were compared at $P \leq 0.05$ by Duncan's multiple range test.

Results and Discussion

Growth characteristics of caraway plant

Data presented in table 1 revealed that, decapitation of the caraway plant either alone or in combination with ADY application at its two levels had a little effect on caraway plant height in comparison to the control. On the other hand, decapitation of the caraway plant alone significantly increased number of branches/plant. A further increase in the number of branches was attended by ADY application. Foliar application of ADY at 2g/l only significantly increased plant height by 3.74 %, as compared to the control. However, number of branches/plant was significantly increased at both ADY levels compared to the control.

Stem and root anatomy of caraway plant

Data presented in table 2 and figure 1 revealed that, generally, all anatomical measurements of caraway stem were increased with decapitation and ADy application as compared to the control (intact unsprayed plants). Active dry yeast application at its high level (2g/l) resulted in the highest increase in stem section diameter (42.34 and 11.45%), in intact and decapitated caraway stem, respectively. Such increase mainly, due to increasing of cortex thickness, (10 and 26.13%), vascular bundle number by 10 and 39.53%, number of oil glands (85 and 27.27%), oil gland diameter by 44.74 and 22.73% and stem pith

diameter by 42.28 and 15.75% in intact and decapitated stem, respectively in comparison to the control. Root (Table 3 and Fig. 2) where decapitation process increased root measurements i.e. section diameter, vascular cylinder diameter, phelloderm thickness and number of secondary xylem vessels bundle. Further increases in these traits were resulted from active dry yeast application for decapitated and intact caraway plant in comparison to the control (intact unsprayed plant). Decapitation process plus ADY at its high level (2g/l.) gave the highest increase in root section diameter by 23.93 and 19.91%, vascular cylinder diameter by 52.72 and 30.41%, phelloderm thickness by 27.27 and 12.5 % and average of secondary xylem vessels by 112.96 and 42.75 % as compared to the control.

Nutrient status of caraway plant

Macro elements %

As shown in table 4 all treatments had a slight effect on N% of rates, except decapitation process plus active dry yeast level (2g/l.), at which root N% was significantly increased in comparison to the control. In shoots, N% was significantly increased in both decapitated and intact caraway plants with active dry yeast application as compared to untreated plants. In this concern, no significant differences were found between both ADY levels. Both P and K% in roots and shoots of the caraway plant were significantly increased by the decapitation process either alone or plus ADY application. The highest increase values were found for P% (180 and 90 %) and K% (149.3 and 60.5 %) in roots and shoots of the decapitated caraway plant, respectively at the highest ADY level in comparison to the control. The addition of ADY especially its high level (2g/l) to intact caraway plant significantly increased P and K% in both roots and shoots of caraway, only P% in shoots was in significantly increased as compared to the control. Data in table 5 showed that, the decapitation process alone had a little effect on both Mg and Ca% of Caraway plant, at which only Ca% in caraway roots was significantly increased in comparison to the control. Addition of ADY at its two levels to decapitated and intact caraway plant significantly increased Mg and Ca % in roots and shoots of plant. The highest Ca an Mg values were resulted from the decapitation process plus ADY application at its high level.

Micro elements

The results in table 6 similar to the showed in table 4 and 5 where decapitation process alone had a slight effect on micro elements only Mn % in roots and shoots of the caraway plant were significantly increased as compared to those of intact plants. Application of Active dry yeast plus decapitation of the caraway plant significantly increased of Fe, Zn and Mn % in roots and shoots of caraway as compared to the control. The highest increases values were shown in roots and shoots of decapitated caraway plants which sprayed with the high ADY level comparing to unsprayed plants. A similar trend was shown in intact caraway plants plus ADY application, but to a lesser extent.

Oil yield and total carbohydrates %

As presented in table 7, decapitated caraway plants produced an oil yield higher than that of intact plants as a control. Moreover, oil % and oil yield were significantly increased with the active dry yeast addition either to decapitated or intact caraway plant in comparison to the untreated plants. Such increase was more pronounced in decapitated caraway plants. The highest increase in oil yield was attained due to the

high level of active dry yeast. With respect to total carbohydrates %, only active dry yeast application at the high level significantly increased the total carbohydrates % of decapitated caraway plants as compared to the control. On the other hand, total carbohydrates% in shoots of intact and decapitated caraway plants, significantly increased due to ADY, mainly the highest level.

Yield and its components of caraway plant

All yield and their component characters were significantly increased by the decapitation process either alone or with active dry yeast application (Table 8). In this respect, no significant differences were found between both active dry yeast levels. Caraway decapitation plants had been higher fruit yield than that of intact plants either alone or with the active dry yeast addition. Such increase in fruit yield was attained from the increasing number of branches/plant (Table 1), number of umbles/plant, and number of umblets/umbel (Table 2). In caraway intact plant only number of umbels and fruits yield/plant were significantly increased by the highest ADY level 2g/l, which gave the best results for all yield traits. At which, number of umbels plant^{-1} (17.51 and 13.48%), number of umblet/umbels (47.37 and 24.65%), dry seed yield plant^{-1} (52.26 and 10.56) and dry seed yield hectare^{-1} (1.28 and 23.81%) were exceeded those of control plants for intact and decapitated caraway plant respectively.

Caraway plant was responded to decapitation process and such response was greatly improved with the active dry yeast application. It is clear from the results in Tables 1 and 2 that decapitation process either alone or plus active dry yeast application resulted in improving growth parameters, i.e. plant height and branches number (Table 1) which reflected on increasing in number of umbles/plant, number of umblets/umble and consequently fruits yield were increased (Table 8). These results are confirmed with those obtained by Shimizu-Sato *et al.* (2009). They suggested that apical dominance is regulated by two plant hormones, auxin and CK. Auxin derived from an intact shoot apex suppresses axillary bud outgrowth, whereas cytokinin induced by decapitation of the shoot apex stimulates the axillary bud outgrowth. They also reported that the effects of CK in apical dominance are antagonistic to those of auxin. Direct application of CK to axillary buds promotes the axillary bud outgrowth, even intact plants. Simulative vegetative growth by using ADY may be due to its influence on the nutritional signal transduction producing growth regulators. It is also a natural source of cytokinins that stimulates cell proliferation and differentiation, controlling shoot and root morphogenesis and chloroplast maturation (Amer, 2004). The present results are in agreement with those obtained by Ezz El-Din and Hendaway (2010) on *Borago officinalis* plant and Ismail *et al.* (2014) on *Silybum marianum.*

Increasing fruit yield of the caraway plant might be due to the resultant increase in number of umbles/plant and number of umblets/umbel and those might be closely related to the beneficial role of yeast during vegetative and reproductive growth through improving flower formation and their set of plants due to its greater content of mineral and certain hormones, mainly auxins and cytokinins (Barnett *et al.,* 1990). In this concern, the present results are in agreement with those obtained by, Khalil and Ismail (2010) on *Lupinus termis*, Hammad and Osama (2014) on wheat plants. They reported that yeast application increased yield and its attributes.

Table.1 Effect of exogenous ADY application on plant height and number of branches/plant in both intact and decapitated caraway plants

Treatment	Plant height (cm)	No. of branches/plant
Int.	112.3± 0.33bc	9.5 ± 0.29d
Dec.	107.5 ± 1.04d	21.5 ± 0.76b
Dec. +1Y.	112.0 ± 1.15bc	26.0 ± 1.00a
Dec. +2Y.	112.7 ± 0.88ab	26.8 ± 0.60a
Int. +1Y.	115.7 ± 0.73ab	11.2 ± 0.30cd
Int. +2Y.	116.5 ± 0.87a	14.0 ± 0.29c
Means	**112.78**	**18.17**

Mean values (n = 9) in the same column for each trait with the same lower small or upper bold-case letter are not significantly different by Duncan's multiple range test at $P \leq 0.05$.
Int. = Intact; Dec. = Decapitation; Y= Yeast; cm = centimeter; No. = number..
Measurements were made in 90-day-old plants.

Table.2 Effect of Exogenous ADY application on anatomical characters of stem in both intact and decapitated caraway plants

Treatment	Av. No. of xylem vessels bundle	Section diameter (µ)	No. of vascular bundle	Av. Cortex Thickness (µ)	No. of Oil glands	Pith Diameter (µ)	Av. Vascular Bundle Length (µ)	Av. Vascular Bundle Width (µ)	Av. gland diameter (µ)
Int.	13.70	5125.0	40	275.0	40	3375	442.5	147.5	38
Dec.	17.50	6000.0	43	310.0	44	4125	482.5	200.0	44
Dec.+1Y.	15.10	6375.0	43	357.5	56	4187	595.0	180.0	41
Dec.+2Y.	17.30	6687.5	60	392.5	42	4775	442.5	186.4	54
Int.+1Y.	22.50	5437.0	38	347.5	42	3687	557.5	180.0	36
Int.+2Y.	19.50	7487.0	44	487.5	74	4937	667.5	177.5	55
Means	**17.60**	**6185.16**	**44.67**	**361.67**	**49.67**	**4181**	**531.25**	**178.50**	**44.67**

Mean values (n = 1). Int. = Intact; Dec. = Decapitation; Y= Yeast; µ = micrometer; Measurements were made in 90-day-old plants.

Table.3 Effect of exogenous ADY application on anatomical characters of root in both intact and decapitated caraway plants

Treatment	Section diameter (µ)	Vascular cylinder diameter (µ)	Phelloderm Thickness (µ)	Av. of secondary xylem vessels (µ)
Int.	2975	1375	550	27.00
Dec.	3450	1687	800	49.80
Dec. +1Y.	4062	2137	875	66.75
Dec. +2Y.	4137	2200	900	71.00
Int. +1Y.	3375	1687	600	66.20
Int. +2Y.	3687	2100	700	57.50
Means	**3614.33**	**1864.33**	**737.5**	**56.38**

Mean values (n = 1). Int. = Intact; Dec. = Decapitation; Y= Yeast; µ = micrometer;
Measurements were made in 90-day-old plants.

Table.4 Effect of Exogenous ADY application on N, P and K % in both intact and decapitated caraway plants

Treatment	N%		P%		K%	
	root	shoot	root	shoot	root	shoot
Int.	0.85±0.05b	1.14±0.06b	0.05±0.01c	0.11±0.003c	0.69±0.02f	1.47±0.02d
Dec.	1.13±0.11ab	1.68±0.21ab	0.07±0.01c	0.15±0.003b	1.25±0.01**c**	1.86±0.05**c**
Dec.+1Y.	1.30±0.12ab	2.00±0.08a	0.11±0.00b	0.20±0.007a	1.42±0.00b	2.14±0.01b
Dec.+2Y.	1.37±0.03a	2.11±0.13a	0.14±0.01a	0.21±0.015a	1.72±0.00a	2.36±0.03a
Int.+1Y.	1.15±0.15ab	1.80±0.15a	0.07±0.01c	0.14±0.012bc	0.93±0.02e	1.76±0.04c
Int.+2Y.	1.21±0.09ab	1.87±0.09a	0.10±0.01b	0.14±0.003bc	1.05±0.01d	1.87±0.04c
Means	**1.17**	**1.77**	**0.09**	**0.16**	**1.18**	**1.91**

Mean values (n = 9) in the same column for each trait with the same lower small or upper bold-case letter are not significantly different by Duncan's multiple range test at $P \leq 0.05$. Int. = Intact; Dec. = Decapitation; Y= Yeast; N= Nitrogen; P= phosphorus; K= potassium. Measurements were made in 90-day-old plants.

Table.5 Effect of Exogenous ADY application on Mg and Ca% in both intact and decapitated caraway plants

Treatment	Mg%		Ca%	
	root	shoot	root	shoot
Int.	7.87±0.74d	12.10±0.35c	0.87±0.07d	0.80±0.05d
Dec.	9.57±0.24cd	13.83±0.32bc	1.33±0.09bc	0.94±0.04cd
Dec.+1Y.	11.10±0.20bc	14.37±0.56b	1.57±0.07ab	1.19±0.04ab
Dec.+2Y.	13.00±0.15a	16.43±0.07a	1.68±0.03a	1.31±0.04a
Int.+1Y.	10.13±0.35bc	14.33±0.52b	1.22±0.04c	1.11±0.00bc
Int.+2Y.	11.93±0.23ab	14.13±0.20b	1.32±0.01bc	1.31±0.02a
Means	**10.60**	**14.20**	**1.33**	**1.11**

Mean values (n = 9) in the same column for each trait with the same lower small or upper bold-cases are not significantly different by Duncan's multiple range test at $P \leq 0.05$. Int. = Intact; Dec. = Decapitation; Y= Yeast; Mg= Magnesium; Ca= Calcium. Measurements were made in 90-day-old plants.

Table.6 Effect of Exogenous ADY application on Fe, Zn and Mn% in both intact and decapitated caraway plants

Treatment	Fe%		Zn%		Mn%	
	root	shoot	root	shoot	root	shoot
Int.	5.94±0.18b	3.72±0.08c	0.12±0.003c	0.14±0.003c	0.05±0.009d	0.10±0.003d
Dec.	6.17±0.18b	4.08±0.25bc	0.14±0.012bc	0.18±0.013bc	0.08±0.006bc	0.21±0.006c
Dec.+1Y.	6.48±0.09b	4.26±0.03bc	0.16±0.007bc	0.18±0.006b	0.10±0.007b	0.14±0.007bc
Dec.+2Y.	7.13±0.11a	5.03±0.05a	0.20±0.015a	0.21±0.003a	0.14±0.006a	0.17±0.006a
Int.+1Y.	6.05±0.17b	3.82±0.10c	0.13±0.012bc	0.16±0.007b	0.06±0.009cd	0.14±0.012c
Int.+2Y.	6.49±0.04b	4.49±0.02ab	0.17±0.006ab	0.20±0.003a	0.13±0.003a	0.19±0.013ab
Means	**6.38**	**4.23**	**0.15**	**0.18**	**0.09**	**0.16**

Mean values (n = 9) in the same column for each trait with the same lower small or upper bold-case letter are not significantly different by Duncan's multiple range test at $P \leq 0.05$. Int. = Intact; Dec. = Decapitation; Y= Yeast; inflour. = inflourences; Zn= Zinc; Mn= Manganese. Measurements were made in 90-day-old plants.

Table.7 Effect of exogenous ADY application on oil % and total carbohydrate % in both intact and decapitated caraway plants

Treatment	Oil %	Yield of oil (kgha^{-1})	Total carbohydrate %	
			root	shoots
Int.	1.40±0.08d	7.82±0.06d	2.45±0.18b	5.76±0.19b
Dec.	3.57±0.12a	8.38±0.05c	2.84±0.17ab	6.81±0.37ab
Dec.+1Y.	2.67±0.08c	8.89±0.03b	3.00±0.09ab	6.82±0.18a
Dec.+2Y.	3.00±0.06bc	10.41±0.04a	3.32±0.09a	7.20±0.21a
Int.+1Y.	3.30±0.06b	7.85±0.03d	2.74±0.05ab	5.99±0.03b
Int.+2Y.	3.73±0.09a	7.92±0.03d	2.74±0.11ab	6.90±0.14a
Means	**2.95**	**8.54**	**2.84**	**6.58**

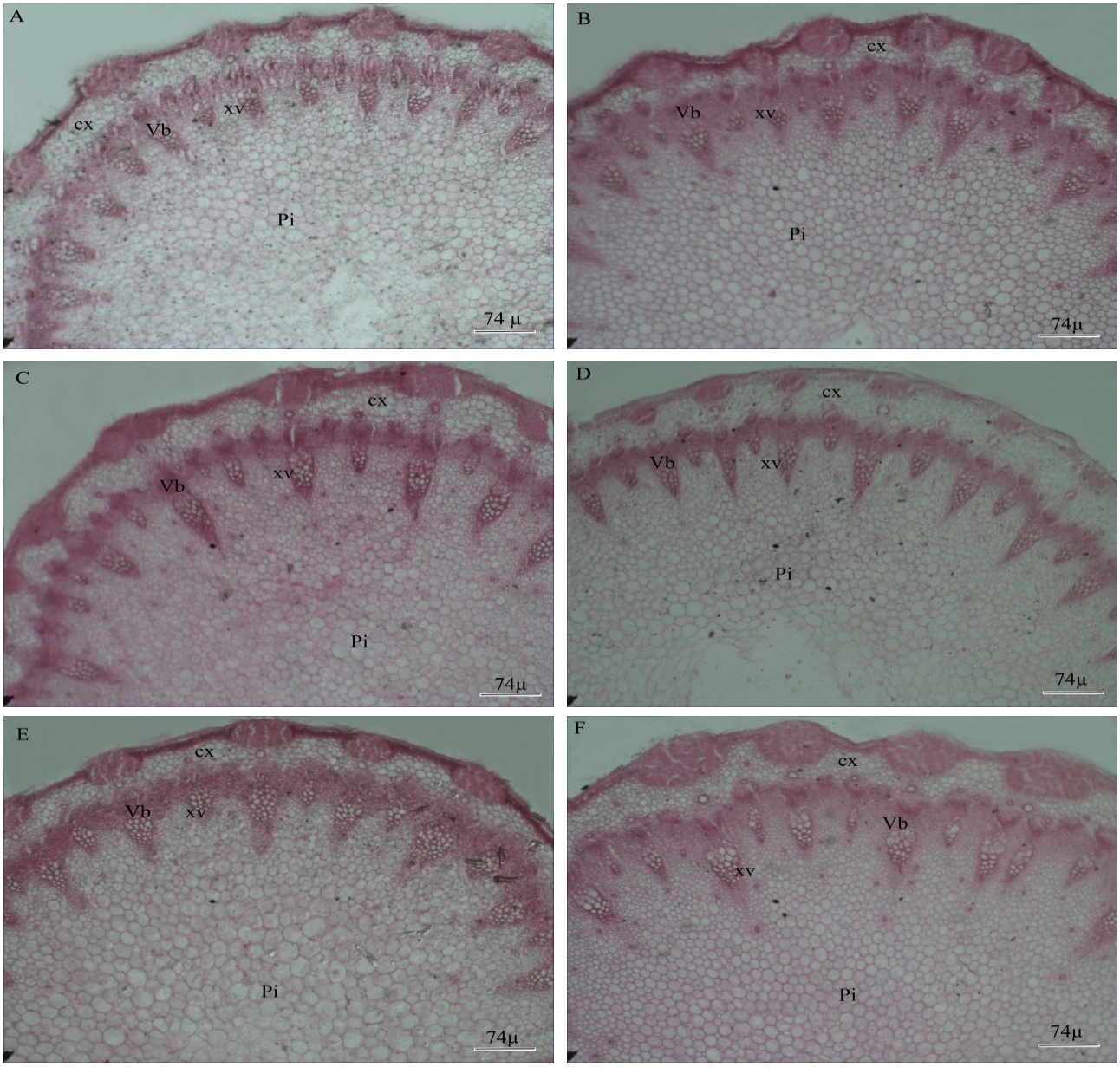
Mean values (n = 9) in the same column for each trait with the same lower small or upper bold-case letter are not significantly different by Duncan's multiple range test at $P \leq 0.05$.
Int. = Intact; Dec. = Decapitation; Y= Yeast, kg=kilogram, ha= hectare
Measurements were made in 90-day-old plants.

Table.8 Effect of Exogenous ADY application on No. of umbles/plant, No. of umblet/umbles, Yield/plant (g), Yield ha^{-1} (ton) in both intact and decapitated caraway plants

Treatment	No. of umbles/plant	No. of umblet/umbles	Yield/plant (g)	Yield/ha (ton)
Int.	50.8 ± 1.09d	15 ± 0.50b	9.5±0.25c	0.78±0.004d
Dec.	77.1 ± 0.75b	18.8 ± 0.83ab	16.1±0.45ab	0.84±0.005c
Dec.+1Y.	85.0 ± 1.15a	19.5 ± 0.76a	16.3±1.08ab	0.89±0.003b
Dec.+2Y.	87.5 ± 0.76a	19.5 ± 0.76a	17.8±0.66a	1.04±0.004a
Int.+1Y.	53.5 ± 0.75d	16.0 ± 0.58ab	12.8±0.62bc	0.78±0.003d
Int.+2Y.	59.7 ± 0.33c	17.7 ± 0.73ab	14.5±1.32ab	0.79±0.003d
Means	**68.93**	**17.83**	**14.5**	**0.85**

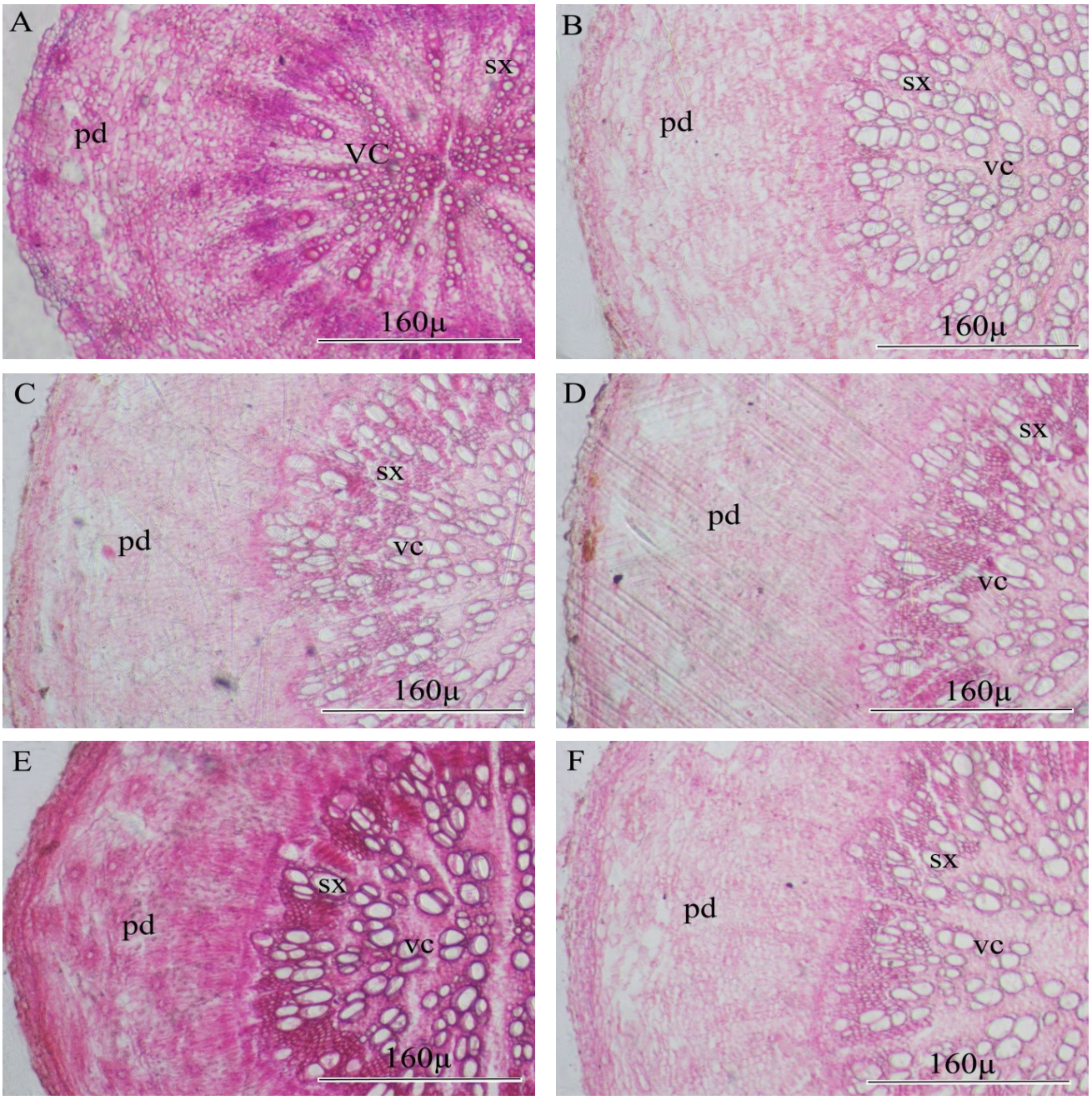
Mean values (n = 9) in the same column for each trait with the same lower small or upper bold-case letter are not significantly different by Duncan's multiple range test at $P \leq 0.05$.
Int. = Intact; Dec. = Decapitation; Y= Yeast; g = gram; ha = hectare;
Measurements were made in 90-day-old plants.

Fig.1 Effect of Exogenous ADY application on anatomical characters of stem in both intact and decapitated caraway plants



A: Control (Intact); B: Control (Decapitation); C: Decapitation+ 1gADY; D: Decapitation+ 2gADY; E: Intact+ 1gADY; F: Intact+ 2gADY.
(cx=cortex; vb= vascular bundle; xv=xylem vessel; Pi = Pith).

Fig.2 Effect of Exogenous ADY application on anatomical characters of root in both intact and decapitated caraway plants



A: Control (Intact); B: Control (Decapitation); C: Decapitation+ 1gADY; D: Decapitation+ 2gADY; E: Intact+ 1gADY; F: Intact+ 2gADY.
(pd=phelloderm; vc= vascular cylinder; sx=secondary xylem).

Improving anatomical measurements (Tables 3 and 4) in root and stem of the caraway decapitated plant with or without ADY application might be attributed to the role of phyto-hormones mainly CK in cell division and enlargement. Where roots are the main CK producing organ in plants and CK bio-synthesized in the root system is

transported into the shoot system via the xylem (Hopkins and Huner, 2004). Shimizu-Sato *et al.* (2009) reported in chickpea that, CK levels in axillary buds were increased after decapitation process and axillary bud outgrowth is correlated with the CK levels. In this concern our results are in agreement with those obtained by Abbas (2013) and Nassar *et al.* (2011). Increasing macro and micro elements in roots and shoots of the caraway plant (Table 5, 6 and 7) with decapitation might be due to the phytohormones balance in the plant which induces after the decapitation process. The positive effect of ADY application with respect to macro and micro elements, mainly attributed to the effect of yeast, which can play a very significant role in making available nutrient elements for plants, also its contents of macro and microelements, growth regulators and vitamins (Heikal, 2005).

Also, ADY application may be increased absorption of different elements by roots and their translocation to the shoots. Similar results were obtained by Ahmed *et al.* (2011) on potato plant and Hammad and Osama (2014) on wheat. Increasing oil yield and total carbohydrates % by decapitation either alone or plus ADy application (Table 7) may be attributed to the physiological roles of vitamins and amino acids in the yeast, which increased the metabolic process and levels of endogenous hormones i.e. IAA and GA_3 Sarhan and Abdullah (2010) and Clara de Vega *et al.* (2009). Also active dry yeast has stimulatory effect upon the efficiency of photosynthesis process and more photosynthates mainly essential oil and carbohydrates. Similar results were obtained by Khalil and Ismail (2010) on terms, Ezz El-Din and Hendaway, (2010) on *Borago officialis* and Hammad and Osama (2014) on wheat plant.

Caraway plants were responded to decapitation process, since, growth, yield and chemical constituents of the caraway plant were improved. Foliar application with active dry yeast as natural biostimulates especially its high level gave the best results with decapitation process.

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