Influence of planting distances in presence of chemical fertilization and compost on growth, essential oil , artemisinin content and chemical constituents of *Artemisia annua* L. plant.

ABSTRACT

Artemisia annua L. *(*Asteraceae) is an essential annual plant, which is characterized by the treatment of some diseases. The aerial parts contain aromatic volatile oils and non-volatile sesquiterpenes used in the pharmacopoeia. Artemisinin is the most important sesquiterpene and its derivatives are used as a remedy against malaria. This investigation was carried out in the Ornamental Farm of the Hort. Dept., Fac. of Agric, Benha Univ. Egypt, during the two sequent seasons of 2019/2020 and 2020/2021 to study the effect of planting distances and applying fertilization on vegetative growth, chemical constituents and oil of *Artemisia annua* (L) plant. Results showed, in both cuts and seasons that the maximum values of vegetative growth and root parameters were obtained from a planting distances (40*40 cm) and fertilization with 100% organic fertilizers. Besides, the combination between planting distances and fertilization treatments enhanced the chemical compositions of the plant, especially with a (40*40 cm) planting distance and the combination of 100% of organic compost (15m^3/Fed.) and the full and half doses of the chemical fertilizers (F3) in the two cuts at both seasons. Gc-MS analysis of of *Artemisia annua* L.On the other hand, essential oil revealed the presence of 23 components which were identified. The major components were champhore, cis-sabinene hydrate, trans β-ocimene, artemisia ketone, borneol, trans-caryophyllene, myrtenal and β- Selinene.Furthermore, the highest value of artemisinin percentage (1.4 %) was scored by (60*60) with 50% organic compost (7.5m^3per/Fed.) and 50% from the recommended chemical fertilizers (F_2). Consequently, it is preferable to apply the planting distance of (40*40 cm) and apply the F_3 fertilizers combination for enhancing all characteristics of the artemisia plant.

Keywords. *Artemisia annua*, artemisinin content, planting distance, fertilizers, growth and volatile oil .

Introduction

Artemisia is an annual plant belongs to the family Asteraceae, which is included in the Chinese Pharmacopoeia, and is characterized by the treatment of some diseases **(Hall and Clements, 1923).**

Artemisinin extract showed potent antimalarial properties with little or no side effects for the first time in China in 1972. (**Klayman *et al.,* 1984; Klayman, 1985; Balint, 2001; Efferth, 2007).** In addition, it is a major source of artemisinin, which are effective against cancer. Also, it contains leishmania and sesquiterpene lactone which has multi-drug resistance and antimalarial effect. **(Yang and Liew, 1993; Sen *et al.,* 2007)**, has higher flavonoid content used as antioxidants. There are potential uses of Artemisia annua extracts for humans and livestock based on the synergistic effects of the flavonoid artemisinin precursors, etc., including the reported antimalarial effects of traditional A. annua tea. (**Mueller *et al.,* 2004; Blanke *et al.,* 2008)**, and a rich source of antioxidants **(Cai *et al.,* 2004)**.

Several researchers have reported that plant density can alter the interception of photosynthetic active radiation (PAR) and the distribution of light within the canopy, the number of resources including water and nutrients , and the volume of soil available to each plant.

Also, the total acre production is affected by the planting distances, so attention must be paid to its studies, as this affects the number of plants per unit area. **El-Ghawwas *et.al.* (2011)** on *(Artemisia annua*) illustrated that the planting distance (60 x 40cm) improved the vegetative growth of the plant.Also **Choudhari and Choudhary (2013)** on artemisia plant, **Tadesse(2019)** on (*Lavandula anguistifolia*) , **Tadesse(2019)** on *Rosmarinus officinalis*, **Degu and Amano (2020)** on (*Lavandula angustifolia*), and **Mengistu *et.al.* (2021)** on (*Nigella sativa*). cleared the importance of the planting distance on the growth and productivity of these plants.

In recent decades in agricultural production affected the use of NPK fertilizers was responsible for the increase of 33:66% in plant productivity **(Fageria and Baligar, 2005).** Excessive use of chemical fertilizers such as soil salinity, and heavy metal pollution, (H**atamian *et al*., 2020).**However, organic fertilizers contribute to the improvement of various soil properties, including soil structure, microbial activity, facilitation of the environment, and the ability to retain moisture. (**Suresh *et al*., 2004; Shahram and Ordookhani, 2011).** Thus, organic has been used to improve plant growth and productivity and improve the physical and biological properties of the soil (**Zheljazkov and Warman, 2004**). In many studies, organic fertilizers can enhance plant growth and yield productivity (**Naiji and Souri, 2018; Najarian and Souri, 2020). Badalingappanavar *et al*. (2018)** declared that the use of organic fertilizers improves the yield and quality of various plants, and it is possible to replace up to 30% of chemical fertilizers (**Wen *et al*., 2016).** However, many long-term studies have indicated that organic amendments increase the production of plants (**Scotti *et al*., 2015). Mohamed *et.al.* (2021)** suggested that mixing organic and chemical fertilizers improved vegetative growth, seed yield, yield, chemical components, and oil productivity. of ajwain.

Thus, objective of this study was to evaluate the effect of planting distance, and the fertilizations treatments beside the interaction among them on the growth and chemical constituents of *Artemisia annua* plants.

Materials and methods

Experimental location

This investigation was carried out in an open field at the Ornamental Farm of the Department of Horticulture Faculty of Agriculture, Benha University, Egypt during the two sequent seasons of 2019/2020 and 2020/2021 for studying the effect of some agricultural treatments on Artemisia (*Artemisia annua* L) plant.

Plant material :-

Well-established seedlings of Artemisia (27-33 cm in height with 5-7 leaves) were obtained from Ornamental Farm, Hort. Dept., Fac. of Agric, Benha Univ., and the planting process was achieved on the 15th and 21st of March in the first and the second seasons, respectively.

Growing Medium

Artemisia seedlings were planted in clay loamy soil, and the physical and chemical properties of the experiment soil were presented in Table (1). Organic compost was added at levels of 15 m^3 and 7.5 m^3/ Feddan to the plot area (rows), assigned as 100% and 50% organic fertilizer before the planting process during the soil preparation, then the experimental plot (1*1 m^2) was divided into rows. In addition, the organic compost (Pharaohs compost) chemical analysis was presented in Table (2).

Table (1). Physical and chemical properties of the experimental soil

Parameters	Values		Parameters	Values	
A. Mechanical properties			**B. Chemical analysis**		
	(2018-2019)	(2019-2020)		(2018-2019)	(2019-2020)
Coarse sand	6.88 %	5.77 %	Organic matter	1.77%	1.88 %
Fine sand	12.66 %	13.34 %	$CaCO_3$	1.11 %	1.14 %
Silt	26.44 %	28.88 %	Available nitrogen	0.96 %	0.84 %
Clay	54.02 %	52.01 %	Available phosphorus	0.28%	0.35 %
Textural class	Clay loam	Clay loam	Available potassium	0.60 %	0.67%
			pH	7.61	7.57
			EC (dS/m)	0.91	0.97

Table (2). Chemical analysis of the applied compost.

	Season	
	(2018-2019)	(2019-2020)
Weight of 1m^3 (kg/m^3)	510	496
Moisture content %	7	9
Organic matter %	45	49
Organic carbon %	25	29
N %	1.4	1.6
C:N ratio	17.8	18.1
NO_3 – N (ppm)	144	139

NH_3 – N (ppm)	55	60
P %	0.88	0.77
K %	1.3	1.6
Zn %	88	96
Mn (ppm)	96	105
Fe (ppm)	122	115

Experiment factors

The first factor was the planting distance (D) at four measures as follows

D_1: 30*30 with 15 plants/plot

D_2: 40*40 with 12 plants/plot

D_3: 50*50 with 10 plants/plot

D_4: 60*60 with 7 plants/plot

The second factor was combinations among the recommended chemical fertilizers and the organic compost at different rates. As the recommended chemical fertilizers rates were {(urea (48%N), calcium superphosphate (15.5% P_2O_5), and potassium sulfate (48%K_2O) at a rate of 350: 200:150 kg/Fed. according to the Egyptian Ministry of Agriculture and Land Reclamation). In addition, the organic compost was used at two different rates (15 and 7.5 m^3/Fed.). The combinations among the two fertilizer types were as follows:

F_1: 100% of the recommended chemical fertilizer (36g urea, 48g calcium superphosphate, and 24g potassium sulphate/plant).

F_2: 50% of the recommended chemical fertilizer (18g urea, 24g calcium superphosphate, and 12g potassium sulphate/plant) + 50% of the organic compost (7.5 m^3/ Fed.).

F_3: 100% of organic compost 15 m^3/ Fed. and the full and half doses of the recommended chemical fertilizers were added after 45 days from transplanting at three equal doses before the Frist cut, the first dose after 45 days from the transplanting process, then the second dose after 20 days from the first dose while the third after 20 days from the second dose. Whereas the second part was added after the first cut at three equal doses with 15^{th} days interval between them.

Experiment layout

The layout of this experiment was a factorial experiment in Randomized Complete Block Design (RCBD) with two factors the first factor was four planting distances treatments and the second was three combinations from the recommended chemical fertilizers and organic compost treatments. All the twelve treatments had three replicates and each replicate contained three plots area with five plants in each. The plants received normal agricultural practices whenever needed.

Harvesting time

The plants were harvested at the full-blooming stage. The plants were cut twice in each time. The first cut was done on the 15th of July. while, the second cut were done on 1st of October) at the two growing seasons of 2019-2020 and 2020-2021.

Data recorded.

1-Vegetative growth:

The plant height (cm), stem diameter (cm), branches number/plant, fresh and dry weight g/plant, fresh and dry weight of leaves (g) were measured.

2. Root parameters

The root length, number of roots, fresh and dry weight of the roots were calculated

3. Chemical composition

Photosynthetic pigments etc. chlorophyll a, b, and carotenoids (mg/100g F.W.) were calorimetrically determined in leaves according to the method described by **Horwitz,W.; Latimer,G.W. (1990).** Also, the nitrogen, phosphorus, potassium, and total carbohydrates were determined in the dried leaves at the flowering stage according to **Horneck and Miller (1998)**, **Hucker and Catroux (1980), Horneck and Hanson (1998)** and **Herbert *et al.* (1971)**, respectively. Furthermore, the **essential oil percentage was determined as**

described in the **British Pharmacopoeia (1963)**. In addition, the determination of the **(Bilia *et al.* 2006).**

and the GC/MS analysis of the essential oil was achieved according to **Guenther (1961)** and **British Pharm. (1963).**

Statistical analysis

The means of all obtained data from the studied factors were subjected to analyses of variance (ANOVA) as a factorial experiment in a complete randomized block design). The differences between the mean values of various treatments were compared by using the least significant differences (LSD) at 5%, as given by (**Snedecor and Cochran 1989**) using MSTAT-C statistical software package**.**

Results and Discussions

1. Impact of planting distances and fertilization treatments and their combination on Vegetative growth measurements:

Tables (3:6) illustrated that all vegetative growth measurements i.e., plant height (cm) , N. of branches number /plant, stem diameter(cm) ,fresh weight of plant (g), dry weight of plant (g) , fresh weight of leaves(g), dry weight of leaves(g) of artemisia (*Artemisia annua* L) plant increased by using planting distance especially (40*40 cm) in the two cuts and in both seasons.

Referring to fertilizer treatments, data showed that all the above-mentioned vegetative growth parameters were greatly affected by all fertilizer treatments in both cuts in both seasons. Hence, the values in these parameters were statistically induced by F_3 (100% organic fertilizers (15m^3 / feddan of compost), followed by F_2 (50% chemical fertilizer and 50% organic). Whereas F_1 (100% chemical fertilizers ranked the third value in this concern. Furthermore, the combination effect between planting distances and fertilization treatments, data in the same Tables revealed that all combinations between planting distances and fertilization treatments increased all parameters of artemisia mentioned afore of Artemisia. This trend was true during two cuts in both seasons of this study. However, the highest values were recorded by using the combined treatment between planting distances (40*40 cm) and F_3, then the combined treatment between planting distances (60*60 cm) and F_3 in the two cuts and seasons in most cases. The combined treatment between planting distances (40*40 cm) and F_2 ranked the third values in this context in most cases in the two cuts and in both seasons.

Table (3) Impact of planting distance and fertilization treatments and their combination treatments on Plant height (cm) and N. of branches/plant of artemisia plant during 2019-2020 and 2020-2021seasons

Parameters	Plant height (cm)								N. of branches/plant							
cutting	1st cut				2nd cut				1st cut				2nd cut			
Fertilization treatments (B) / Plant distance (A)	B				B				B				B			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
1st season																
30*30	199.67	201.33	210.00	203.67	172.67	186.67	195	184.78	33.00	37.00	40.00	36.67	132.67	134.67	136.33	134.57
40*40	206.00	207.00	210.67	207.89	183.67	185.00	195.00	187.89	37.00	38.67	40.33	38.67	137.67	138.00	140.00	138.57
50*50	203.67	206.00	207.00	205.56	171.33	174.00	179.00	174.78	33.33	35.67	37.33	35.44	130.33	132.67	136.67	133.22
60*60	205.33	206.33	208.33	206.67	183.33	184.67	185.67	184.56	34.33	37.00	39.67	37.00	135.33	137.33	141.00	137.89
Mean	203.67	205.17	209.00		177.75	182.58	188.67		34.42	37.08	39.33		134.00	135.67	138.50	
L.S.D at 0.05 for	A=2.155 B=1.867 AXB=3.733				A=3.339 B=2.892 AXB=5.784				A=2.339 B=2.026 AXB=4.052				A= 2.169 B=1.878 AXB=3.757			
2nd season																
30*30	197.33	202.33	204.33	201.33	173.67	184.00	192.33	183.33	33.33	35.00	38.67	35.67	131.33	132.67	136.67	133.56
40*40	205.00	206.67	207.67	206.44	183.67	185.33	186.67	185.22	35.00	37.33	40.00	37.44	134.33	135.00	137.67	135.67
50*50	201.67	205.00	209.00	205.22	168.33	171.33	175.33	171.67	32.67	34.33	35.67	34.22	129.67	132.67	134.00	132.11
60*60	202.67	206.00	208.00	205.57	180.67	182.67	185.67	183.00	34.33	36.33	38.00	36.22	132.67	135.00	136.67	134.78
Mean	201.67	205.00	207.25		176.58	180.83	185.00		33.83	35.75	38.08		132.00	133.83	136.25	
L.S.D at 0.05 for	A= 2.430 B=2.105 AXB=4.209				A=2.742 B=2.375 AXB=4.750				A= 2.103 B=1.821 AXB=3.642				A= 3.001 B=2.599 AXB=5.198			

F_1= 100% R.D. of chemical fertilizers , F_2=50% R.D. of chemical fertilizer and 50% organic fertilizer , F_2= 100% organic fertilizer (15m^3 / feddan of compost

Table (4) Impact of planting distance and fertilization treatments and their combination treatments on stem diameter(cm)and fresh weight of plant (g)of artemisia plant during 2019-2020 and 2020-2021seasons

Parameters	Stem diameter(cm)								Fresh weight of plant (g)							
cutting	1st cut				2nd cut				1st cut				2nd cut			
Fertilization treatments (B) / Plant distance (A)	B				B				B				B			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
1st season																
30*30	1.00	1.07	0.93	1.00	0.83	0.93	0.80	0.86	127.33	129.33	132.00	129.56	152.67	154.33	157.00	154.67
40*40	1.00	0.80	1.03	0.94	0.90	0.70	0.83	0.81	150.00	160.00	180.00	163.33	182.67	184.00	192.33	186.33
50*50	0.87	0.93	1.07	0.96	0.77	0.80	0.80	0.79	135.00	165.00	167.67	155.89	150.00	155.00	175.67	160.22
60*60	0.97	1.20	1.17	1.11	0.70	0.80	0.90	0.80	160.00	163.00	165.33	162.78	183.00	185.67	188.00	185.56
Mean	0.96	1.00	1.05		0.80	0.81	0.83		143.08	154.33	161.25		167.08	169.75	178.25	
L.S.D at 0.05 for	A=0.138 B=0.120 AXB=0.240				A=0.116 B=0.100 AXB=0.200				A=3.830 B=3.317 AXB=6.633				A=3.380 B=2.927 AXB=5.854			
2nd season																
30*30	0.80	0.77	0.80	0.79	0.57	0.67	0.73	0.66	127.67	129.33	132.33	129.78	150.00	153.33	155.00	152.78
40*40	0.88	1.03	0.73	0.88	0.60	0.67	0.67	0.64	152.67	157.67	178.33	162.89	180.67	183.00	190.67	184.78
50*50	1.03	1.00	1.03	1.02	0.63	0.73	0.77	0.71	140.00	160.67	161.33	154.00	150.00	153.67	171.00	158.22
60*60	0.90	1.07	1.00	0.99	0.53	0.70	0.90	0.71	158.00	161.00	164.67	161.22	181.33	184.00	187.67	184.33
Mean	0.90	0.97	0.89		0.58	0.69	0.77		144.58	152.17	159.17		165.50	168.50	176.08	
L.S.D at 0.05 for	A=0.175 B=0.152 AXB=0.303				A=0.124 B=0.107 AXB=0.214				A=2.801 B=2.426 AXB=4.852				A=3.222 B=2.790 AXB=5.580			

F_1= 100% R.D. of chemical fertilizers, F_2=50% R.D. of chemical fertilizer and 50% organic fertilizer , F_2= 100% organic fertilizer (15m^3 / feddan of compost

2. Impact of planting distance and fertilization treatments and their combination on root parameters

Data in Tables (6 and 7) reveals that, planting distances (40*40 cm) score the highest increases of fresh weight of root(g) , dry weight of root(g), N. of roots/plant and root length (cm) .

Table (5) Impact of planting distance and fertilization treatments and their combination treatments on dry weight of plant(g)and fresh weight of leaves (g)of *Artemisia Annua* L. Plant during 2019-2020 and 2020-2021seasons

Parameters	Dry weight of plant(g)								Fresh weight of leaves(g)							
cutting	1st cut				2nd cut				1st cut				2nd cut			
Fertilization treatments (B) / Plant distance (A)	Fertilization treatments				Fertilization treatments				Fertilization treatments				Fertilization treatments			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
1st season																
30*30	45.00	47.33	51.00	47.78	52.00	54.00	56.33	54.11	30.98	35.30	47.78	38.02	50.51	58.98	64.01	57.83
40*40	71.67	75.33	81.33	76.11	90.33	93.00	95.33	92.89	44.53	45.97	53.21	47.90	54.99	61.02	64.31	60.10
50*50	65.00	68.00	81.67	71.56	85.33	88.00	93.00	88.78	40.12	45.77	50.32	45.40	52.33	57.01	66.00	58.45
60*60	67.67	76.00	82.67	75.44	87.67	89.33	95.33	90.78	42.52	45.05	52.09	46.55	55.14	59.88	64.92	59.98
Mean	62.33	66.67	74.17		78.83	81.08	85.00		39.54	43.02	50.85		53.24	59.22	64.81	
L.S.D at 0.05 for	A=2.663 B=2.307 AXB=4.613				A=2.829 B=2.450 AXB=4.901				A=2.157 B=1.868 AXB=3.736				A=3.421 B=2.963 AXB=5.925			
2nd season																
30*30	42.67	45.67	50.00	46.11	51.00	53.00	55.67	53.22	29.20	33.39	45.51	36.03	50.41	57.30	63.07	56.92
40*40	70.67	73.33	81.00	75.00	85.00	92.00	93.33	90.11	43.38	45.09	50.80	46.42	53.90	58.07	64.24	58.73
50*50	65.00	66.67	80.33	70.67	83.33	89.00	91.33	87.89	39.62	43.95	50.53	44.70	51.43	56.35	64.95	57.58
60*60	65.67	75.00	83.33	74.67	86.33	88.00	94.33	89.56	40.43	45.62	51.72	45.92	51.93	60.28	62.93	58.38
Mean	61.00	65.17	73.67		76.42	80.50	83.67		38.16	42.01	49.64		51.92	57.99	63.80	
L.S.D at 0.05 for	A=2.435 B=2.108 AXB=4.217				A=3.197 B=2.769 AXB=5.537				A=1.961 B=1.699 AXB=3.397				A=3.543 B=3.069 AXB=6.137			

F_1= 100% R.D. of chemical fertilizers, F_2=50% R.D. of chemical fertilizer and 50% organic fertilizer , F_2= 100% organic fertilizer (15m^3 / feddan of compost

Table (6) Impact of planting distance and fertilization treatments and their combination treatments on dry weight of leaves(g)and fresh and dry weights of roots (g)of artemisia plant during 2019-2020 and 2020-2021seasons.

Parameters	Dry weight of leaves(g)								Fresh weight of roots(g)				Dry weight of roots(g)			
cutting	1st cut				2nd cut											
Fertilization treatments (B) / Plant distance (A)	B				B				B				B			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
1st season																
30*30	6.87	9.62	12.48	9.66	17.99	21.06	22.76	20.60	9.74	11.58	14.51	11.94	3.78	4.31	6.69	4.93
40*40	13.80	16.05	18.49	16.11	25.43	28.81	31.61	28.62	14.70	18.98	25.45	19.71	4.98	6.88	10.96	7.60
50*50	9.14	13.50	17.82	13.49	18.93	22.70	28.39	23.34	14.84	16.04	17.37	16.09	4.77	5.26	7.41	5.82
60*60	11.64	13.81	17.94	14.46	19.20	25.22	27.22	23.88	14.44	18.25	18.70	17.13	5.50	6.44	7.87	6.60
Mean	10.36	13.25	16.68		20.39	24.45	27.50		13.43	16.21	19.01		4.76	5.72	8.23	
L.S.D at 0.05 for	A=1.989 B=1.722 AXB=3.445				A=2.553 B=2.211 AXB=4.422				A=1.206 B=1.045 AXB=2.090				A=0.943 B=0.817 AXB=1.633			
2nd season																
30*30	8.53	9.97	11.67	10.06	19.03	20.36	21.70	20.36	9.70	11.17	12.30	11.06	3.60	4.26	5.13	4.33
40*40	12.47	16.30	17.54	15.44	22.81	27.10	28.33	26.08	14.30	18.80	22.76	18.62	4.77	6.60	8.89	6.75
50*50	8.88	12.76	16.10	12.58	17.61	22.12	26.37	22.03	13.87	15.80	13.90	14.52	3.75	4.29	6.56	4.87
60*60	11.80	13.83	15.80	13.81	20.20	24.90	30.80	25.30	13.88	17.67	18.03	16.52	4.41	5.80	7.60	5.94
Mean	10.42	13.21	15.28		19.91	23.62	26.80		12.94	15.86	16.75		4.13	5.24	7.05	
L.S.D at 0.05 for	A=1.971 B=1.707 AXB=3.14				A=2.510 B=2.174 AXB=4.347				A=1.116 B=0.967 AXB=1.934				A=1.085 B=0.940 AXB=1.879			

F_1= 100% R.D. of chemical fertilizers, F_2=50% R.D. of chemical fertilizer and 50% organic fertilizer , F_2= 100% organic fertilizer (15m^3 / feddan of compost

Table (7) Impact of planting distance and fertilization treatments and their combination treatments on N. of roots/plant and fresh, root length (cm) and chlorophyll a of artemisia plant during 2019-2020 and 2020-2021seasons.

Parameters	N. of roots/plant				Root length (cm)				Chlorophyll a							
cutting									1st cut				2nd cut			
Fertilization treatments (B) / Plant distance (A)	B				B				B				B			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
1st season																
30*30	7.33	8.00	11.33	8.89	7.67	8.67	9.33	8.56	0.66	0.79	0.82	0.76	0.47	0.49	0.57	0.51
40*40	8.67	12.00	13.00	11.22	10.00	11.33	13.00	11.44	1.51	1.67	1.84	1.68	1.19	1.33	1.43	1.32
50*50	5.67	9.67	12.00	9.11	8.00	10.00	10.33	9.44	0.73	0.82	0.90	0.82	0.48	0.54	0.60	0.54
60*60	8.00	11.00	11.33	10.11	9.00	9.67	11.33	10.00	0.96	1.11	1.31	1.13	0.73	0.94	1.11	0.93
Mean	7.42	10.17	11.92		8.67	9.92	11.00		0.97	1.10	1.22		0.72	0.82	0.93	
L.S.D at 0.05 for	A=1.571 B=1.361 AXB=2.721				A=1.614 B=1.398 AXB=2.795				A=0.062 B=0.054 AXB=0.107				A=0.076 B=0.066 AXB=0.131			
2nd season																
30*30	6.67	7.67	9.00	7.78	6.33	8.00	9.00	7.78	0.64	0.78	0.83	0.75	0.45	0.49	0.56	0.50
40*40	7.67	11.33	13.00	10.67	8.33	10.00	10.67	9.67	1.50	1.39	1.03	1.31	1.24	1.43	1.82	1.50
50*50	6.00	9.67	10.00	8.56	8.00	8.33	9.67	8.67	0.66	0.80	0.87	0.77	0.48	0.52	0.59	0.53
60*60	7.33	9.67	11.00	9.33	8.67	9.00	10.00	9.22	0.93	1.13	1.23	1.10	0.67	0.89	1.03	0.86
Mean	6.92	9.58	10.75		7.83	8.83	9.83		0.93	1.02	0.99		0.71	0.83	1.00	
L.S.D at 0.05 for	A=1.401 B=1.213 AXB=2.426				A=1.359 B=1.177 AXB=2.354				A=0.112 B=0.097 AXB=0.193				A=0.093 B=0.080 AXB=0.161			

F_1= 100% R.D. of chemical fertilizers, F_2=50% R.D. of chemical fertilizer and 50% organic fertilizer, F_2= 100% organic fertilizer (15m^3 / feddan of compost

All fertilizers treatments progressively increased root parameters mentioned afore with a superior of F_3 (100% organic fertilizers (15m^3 / feddan of compost), followed by F_2 (50% chemical fertilizer and 50% organic) in the first and second seasons. On the contrary, the lowest values of these parameters were obtained F1 (100% chemical fertilizers).

Additionally, data in Tables (6 and 7) show that all the combinations between planting distances and fertilization treatments statistically increased of parameters mentioned above especially, planting distances (40*40 cm) and F_3, then by the combined treatment between planting distances (60*60 cm) and F_3 in the two seasons. The combined treatment between planting distances (40*40 cm) and F_2 resulted in high increments in this concern. On the opposite, the lowest values of the abovementioned parameters were obtained from the combination of scored by between planting distances (30*30 cm) and F_1 in both seasons.

Similar results were mentioned before for the impact of planting distance on the vegetative growth of *Artemisia annua* by **El-Ghawwas *et.al.* (2011)** illustrated that the planting distance (60 x 40cm) improved the fresh and dry herb yields/plant, **Choudhari and Choudhary (2013)** showed that, 45×60 cm distance scored the maximum leaf yield *Artemisia annua* plant, **Tadesse(2019)** on (*Lavandula Anguistifolia*) and *Rosmarinus officinalis*, **Degu and Amano,(2020)** on (*Lavandula angustifolia*),) and **Mengistu *et.al.* (2021)** on (*Nigella sativa*).

The results are consistent with **Abou El-Ghait et al. (2012)** on Indian fennel, **Shakouri *et.al.*(2014)** on (*Artemisia annua*) , **Omer *et.al.*(2014)** on (*Artemisia annua*), **Elsayed *et.al.* (2020)** on (*Anethum graveolens*), **Ghatas (2020)** revealed that the vegetative growth of coriander increased with a complete dose of mineral fertilizer and height, number of umbels, and seed yield of coriander. **Mohamed *et.al.* (2021)** suggested that mixing organic and chemical fertilizers improved vegetative growth, seed yield, yield, chemical components and oil productivity. of ajwain.**Mirjalili *et.al.*(2022)** on (*Satureja bachtiarica*

Bunge) found that The maximum plant weight was observed with organic fertilizer application at high plant density (HPD) plant density in the second year.

3. Impact of planting distances and fertilization treatments and their combination on chemical constituents

Tables (7:10) demonstrated that the planting distance of (40*40 cm) gave the highest values of chlorophyll a, b, carotenoids content, total carbohydrates%, N%, P% and K% in two both cuts and seasons. Referring to, all the fertilizer treatments progressively maximized, chemical compositions mentioned afore with the superiority of F_3 (100% organic fertilizers (15m^3 / feddan of compost), followed by F_2 (50% chemical fertilizer and 50% organic) in both cuts in the first and second seasons.

Furthermore, the combination between planting distances and fertilization treatments had a significant effect on these parameters per plant.

Table (8) Impact of planting distance and fertilization treatments and their combination treatments on chlorophyll a, b and carotenoids of artemisia plant during 2019-2020 and 2020-2021seasons.

Parameters	chlorophyll b								carotenoids							
cutting	1st cut				2nd cut				1st cut				2nd cut			
Fertilization treatments (B) / Plant distance (A)	B				B				B				B			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
1st season																
30*30	0.53	0.60	0.63	0.59	0.36	0.40	0.42	0.40	0.39	0.44	0.51	0.44	0.13	0.14	0.15	0.14
40*40	0.68	0.91	1.36	0.99	0.53	0.57	0.64	0.58	0.61	0.68	0.73	0.67	0.18	0.19	0.19	0.19
50*50	0.56	0.66	0.71	0.64	0.47	0.54	0.58	0.53	0.51	0.53	0.56	0.53	0.16	0.16	0.18	0.17
60*60	0.61	0.71	0.78	0.70	0.49	0.55	0.60	0.55	0.53	0.60	0.66	0.60	0.17	0.17	0.18	0.18
Mean	0.60	0.72	0.87		0.46	0.52	0.56		0.51	0.56	0.62		0.16	0.17	0.18	
L.S.D at 0.05 for	A=0.093 B=0.080 AXB=0.161				A=0.031 B=0.027 AXB=0.054				A=0.002 B=0.0018 AXB=0.004				A=0.002 B=0.0018 AXB=0.004			
2nd season																
30*30	0.52	0.59	0.64	0.58	0.36	0.38	0.45	0.39	0.37	0.42	0.52	0.44	0.13	0.14	0.15	0.14
40*40	0.66	0.73	0.79	0.73	0.52	0.56	0.60	0.56	0.58	0.66	0.71	0.65	0.18	0.19	0.19	0.19
50*50	0.54	0.64	0.68	0.62	0.46	0.52	0.60	0.53	0.51	0.53	0.54	0.52	0.16	0.16	0.18	0.16
60*60	0.61	0.67	0.77	0.68	0.49	0.54	0.60	0.54	0.50	0.58	0.65	0.58	0.17	0.17	0.18	0.17
Mean	0.58	0.66	0.72		0.46	0.50	0.56		0.49	0.55	0.60		0.16	0.16	0.17	
L.S.D at 0.05 for	A=0.031 B=0.027 AXB=0.054				A=0.031 B=0.027 AXB=0.054				A=0.003 B=0.002 AXB=0.005				A=0.003 B=0.002 AXB=0.005			

F_1= 100% R.D. of chemical fertilizers, F_2=50% R.D. of chemical fertilizer and 50% organic fertilizer, F_2= 100% organic fertilizer (15m^3 / feddan of compost

Table (9) Impact of planting distance and fertilization treatments and their combination treatments on N% and P% of artemisia plant during 2019-2020 and 2020-2021seasons.

Parameters	N%								P%							
cutting	1st cut				2nd cut				1st cut				2nd cut			
Fertilization treatments (B) / Plant distance (A)	B				B				B				B			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
1st season																
30*30	2.14	2.55	2.96	2.55	2.06	2.37	2.82	2.42	0.27	0.28	0.33	0.29	0.26	0.26	0.31	0.28
40*40	3.56	4.04	4.47	4.03	3.50	3.98	4.38	3.95	0.52	0.55	0.58	0.55	0.50	0.54	0.56	0.53
50*50	2.99	3.01	3.08	3.03	2.91	2.79	2.97	2.89	0.33	0.35	0.39	0.36	0.30	0.33	0.37	0.33
60*60	3.08	3.56	3.76	3.46	2.95	3.53	3.58	3.35	0.41	0.45	0.50	0.45	0.39	0.43	0.48	0.43
Mean	2.94	3.29	3.57		2.86	3.17	3.44		0.38	0.41	0.45		0.36	0.39	0.43	
L.S.D at 0.05 for	A=0.342 B=0.296 AXB=0.591				A=0.370 B=0.320 AXB=0.640				A=0.002 B=0.0018 AXB=0.004				A=0.002 B=0.0018 AXB=0.004			
2nd season																
30*30	2.05	2.46	2.80	2.44	1.99	2.30	2.68	2.32	0.25	0.26	0.31	0.27	0.24	0.24	0.29	0.26
40*40	3.52	3.92	4.34	3.93	3.40	3.85	4.20	3.82	0.50	0.53	0.56	0.53	0.48	0.52	0.54	0.51
50*50	2.95	2.85	2.98	2.93	2.89	2.68	2.56	2.71	0.31	0.32	0.37	0.33	0.28	0.31	0.35	0.31
60*60	2.96	3.45	3.64	3.35	2.83	3.44	3.50	3.26	0.38	0.43	0.48	0.43	0.37	0.41	0.46	0.41
Mean	2.87	3.17	3.44		2.78	3.07	3.24		0.36	0.39	0.43		0.34	0.37	0.41	
L.S.D at 0.05 for	A=0.362 B=0.313 AXB=0.627				A=0.359 B=0.311 AXB=0.622				A=0.031 B=0.027 AXB=0.054				A=0.002 B=0.0018 AXB=0.004			

F_1= 100% R.D. of chemical fertilizers, F_2=50% R.D. of chemical fertilizer and 50% organic fertilizer, F_2= 100% organic fertilizer (15m^3 / feddan of compost

Table (10) Impact of planting distance and fertilization treatments and their combination treatments on K% and total carbohydrates %of artemisia plant during 2019-2020 and 2020-2021seasons.

Parameters	K%								Total carbohydrates%							
cutting	1st cut				2nd cut				1st cut				2nd cut			
Fertilization treatments (B) / Plant distance (A)	B				B				B				B			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
1st season																
30*30	1.67	1.71	1.74	1.71	1.64	1.69	1.73	1.69	13.68	15.46	17.02	15.39	13.33	14.30	16.70	14.78
40*40	1.85	1.91	1.97	1.91	1.81	1.89	1.94	1.88	20.24	21.11	22.71	21.36	19.43	20.50	22.10	20.68
50*50	1.70	1.77	1.78	1.75	1.69	1.73	1.76	1.73	17.48	19.56	20.09	19.05	16.46	18.60	19.86	18.31
60*60	1.81	1.85	1.91	1.86	1.78	1.83	1.89	1.83	18.69	20.27	20.80	19.92	18.32	19.42	20.33	19.36
Mean	1.76	1.81	1.85		1.73	1.79	1.83		17.52	19.10	20.16		16.88	18.21	19.75	
L.S.D at 0.05 for	A=0.031 B=0.027 AXB=0.054				A=0.031 B=0.027 AXB=0.054				A=1.246 B=1.079 AXB=2.159				A=1.055 B=0.913 AXB=1.827			
2nd season																
30*30	1.58	1.65	1.69	1.64	1.56	1.63	1.65	1.61	13.48	13.89	16.50	14.62	13.22	13.53	15.52	14.09
40*40	1.81	1.88	1.92	1.87	1.78	1.85	1.91	1.85	19.97	19.79	21.28	20.35	18.54	19.54	21.03	19.70
50*50	1.66	1.70	1.72	1.69	1.63	1.64	1.67	1.65	16.55	19.00	19.31	18.29	15.45	17.69	19.29	17.48
60*60	1.75	1.80	1.84	1.80	1.73	1.77	1.80	1.77	18.64	19.31	20.14	19.36	17.28	18.53	18.98	18.26
Mean	1.70	1.76	1.79		1.67	1.72	1.76		17.16	18.00	19.31		16.12	17.32	18.71	
L.S.D at 0.05 for	A=0.031 B=0.027 AXB=0.054				A=0.044 B=0.038 AXB=0.076				A=1.172 B=1.015 AXB=2.031				A=1.031 B=0.893 AXB=1.786			

F_1= 100% R.D. of chemical fertilizers, F_2=50% R.D. of chemical fertilizer and 50% organic fertilizer, F_2= 100% organic fertilizer (15m^3 / feddan of compost

In both cuts and seasons, the highest values were gained from planting distance(40*40 cm) and F_3, thenby the combined treatment between planting distances (60*60 cm) and F_3 .The lowest values of parameters mentioned above scored by planting distances (30*30 cm) and F_1 in the two cuts and in both seasons.

In this respect, **El-Ghawwas *et.al.* (2011)** on (*Artemisia annua*) found that the widest distance (60 x 40cm) increased chemical composition of plant, **Nurzyńska and Zawiślak (2014)** on (*Artemisia dracunculus,*

Furthermore, **Mousa *et.al.* (2012**) on (*Nigella sativa*), **Heikal (2017)** on (*Artemisia annua*) found that nitrogen nutrition increased total carbohydrate contents up to 60kg (N) and **Elsayed *et.al.* (2020)** on (*Anethum graveolens*).

4. Impact of planting distances and fertilization treatments and their combination on essential oil %

According to data presented in Table (11) declare that planting distances (40*40 cm) score the richest percentage of essential oil of artemisia plant in the two cuts and in both seasons. On the other side, all the fertilizer treatments progressively increased essential oil % with a superior of F_3 (100% organic fertilizers (15m3 / feddan of compost), followed by F_2 (50% chemical and 50% organic) in both cuts in the first and second seasons. However, data in Table (11) show that all the combinations between planting distance and fertilization treatments statistically increased of parameters mentioned above especially, planting distances (40*40 cm) and F_3, then by the combined treatment between planting distances (60*60 cm) and F_3 in the two seasons. The combined treatment between planting distances (40*40 cm) and F2 ranked the third values in this concern. On the opposite, the lowest values in this context were scored by planting distances (30*30 cm) and F_1 in the two cuts and in both seasons.

The essential oil results of planting distance obtained by **Damtew *et.al.* (2011)** on (*Artemisia annua*), **Solomon and Beemnet (2011)** on (*Mentha arvensis*),

Table (11) Impact of planting distance and fertilization treatments and their combination treatments on essential oil %of artemisia plant during 2019-2020 and 2020-2021seasons.

Parameters	Essential oil %							
cutting	1st cut				2nd cut			
Fertilization treatments (B) / Plant distance (A)	B				B			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
1st season								
30*30	0.24	0.26	0.36	0.29	0.46	0.50	0.68	0.55
40*40	0.29	0.36	0.52	0.39	0.58	0.62	0.70	0.63
50*50	0.28	0.35	0.40	0.34	0.51	0.58	0.66	0.58
60*60	0.28	0.37	0.44	0.37	0.54	0.63	0.68	0.62
Mean	0.27	0.34	0.43		0.52	0.58	0.68	
L.S.D at 0.05 for	A=0.062 B=0.054 AXB=0.107				A=0.062 B=0.054 AXB=0.107			
2nd season								
30*30	0.26	0.27	0.31	0.28	0.45	0.48	0.67	0.53
40*40	0.32	0.38	0.45	0.38	0.58	0.61	0.70	0.63
50*50	0.25	0.34	0.38	0.32	0.50	0.57	0.65	0.57
60*60	0.30	0.36	0.42	0.36	0.56	0.60	0.66	0.60
Mean	0.28	0.34	0.39		0.52	0.56	0.67	
L.S.D at 0.05 for	A=0.044 B=0.038 AXB=0.076				A=0.062 B=0.054 AXB=0.107			

F_1= 100% R.D. of chemical fertilizers, F_2=50% R.D. of chemical fertilizer and 50% organic fertilizer, F_2= 100% organic fertilizer (15m^3 / feddan of compost

Selim *et.al.* (2013) on (*Foeniculum Vulgare*), **Lulie and Chala (2016)** on (*Cymbopogon citratus*), **Joshi *et.al.*(2020)** on *Matricaria chamomilla*, **Mirjalili *et.al.*(2022)** on (*Satureja bachtiarica Bunge*) .

Additionally the results of fertilization obtained by, **Heikal (2017)** on artemisia plant, **Mohamed *et.al.* (2021)** on ajwain, **Khater *et.al.*(2022)** on (*coriandrum sativum*) and **Toaima *et.al.*(2022)** on (*Ocimum basilicum* L).

5. Impact of planting distances and fertilization treatments and their combination on Gc-MS analysis of Artemisia plant.

Table (12) and Figures (1: 8) cleared suggested that, Gc-MS analysis for *Artemisia annua* L. essential oil identified 23 component i.e. α-thujene, α – Pinene, camphene, delta-3-carene, sabinene, 1,8 cineole, artemisia ketone, cis-Sabinene hydrate, terpinolene, artemisia alcohol, trans-Sabinene hydrate, t rans β-ocimene, champhore, borneol, terpinene-4-ol, myrtenal, myrtenol, trans-carveol, cis-carveol, eugenol, benzyle 2-methyl butyrate, tranc-caryophyllene, β-farnesene and β- Selinene. Hence, the major components were champhore, cis-Sabinene hydrate, Trans β-ocimene, artemisia ketone, borneol, tranc- Caryophyllene, myrtenal and β- Selinene. In this concern, the combined treatment between planting distances (60*60 cm) and F_3 100% organic fertilizers (15m_3 / feddan of compost) gave the maximum values of champhore as (24.67 %) then by between planting distances (50*50 cm) and F_3 100% organic fertilizers or planting distances (30*30 cm) and F_2 50% chemical fertilizers and 50% organic fertilizers as (17.89%). In general, the combined treatment planting distances (60*60 cm) and F_2 50% chemical fertilizers and 50% organic fertilizers recorded the maximum values of Trans β-ocimene (20.01%)

Table (12) Impact of planting distance and fertilization treatments and their combination treatments on essential oil constituents of artemisia pant during the 2nd cut season 2020-2021

No	Component Name	30*30 +F_2	Component Name	30*30+F_3	Component Name	40*40+F_2	Component Name	40*40 +F_3	Component Name	50*50+ F_2	Component Name	50*50+F_3	Compone nt Name	60*60+F_2	Component Name	60*60+ F_3
1	α-thujene	0.12	α-thujene	0.55	α-thujene	0.88	α-thujene	0.23	α-thujene	0.12	α-thujene	0.12	α-thujene	0.21	α-thujene	0.33
2	α - Pinene	0.72	α - Pinene	2.34	α - Pinene	2.58	α - Pinene	0.32	α - Pinene	0.80	α - Pinene	70.5	α - Pinene	0.51	α - Pinene	1.73
3	Camphene	2.04	Camphene	4.22	Camphene	3.23	Camphene	2.77	Camphene	1.88	Camphene	91.6	Camphene	1.68	Camphene	0.65
4	1,8 cineole	4.79	Sabinene	2.22	Delta-3-carene	1.25	Delta-3-carene	0.23	1,8 cineole	5.11	1,8 cineole	14.3	1,8 cineole	4.79	1,8 cineole	6.23
5	Not Identify	0.82	1,8 cineole	3.65	Sabinene	2.21	Sabinene	4.01	Artemisia ketone	8.88	Not Identify	0.82	Artemisia ketone	5.12	N.I	3.13
6	Artemisia ketone	8.86	Artemisia ketone	8.23	1,8 cineole	4.43	1,8 cineole	5.66	Cis-Sabinene hydrate	3.11	Artemisia ketone	8.86	Cis-Sabinene hydrate	1.78	Artemisia ketone	1.02
7	Cis-Sabinene hydrate	3.04	Cis-Sabinene hydrate	1.90	Artemisia ketone	17.01	Artemisia ketone	14.54	Terpinolene	0.88	Cis-Sabinene hydrate	3.04	Terpinolen e	0.85	Cis-Sabinene hydrate	1.26
8	Terpinolene	0.85	Terpinolene	1.03	Cis-Sabinene hydrate	2.43	Cis-Sabinene hydrate	5.46	Trans-Sabinene hydrate	1.33	Terpinolene	0.85	Trans-Sabinene hydrate	1.41	Terpinolene	-
9	Trans-Sabinene hydrate	1.41	Artemisia alcohol	1.03	Terpinolene	1.65	Terpinolene	0.48	T rans β-ocimene	3.20	Trans-Sabinene hydrate	11.4	T rans β-ocimene	3.52	Trans-Sabinene hydrate	1.41
10	T rans β-ocimene	3.29	Trans-Sabinene hydrate	1.25	Artemisia alcohol	2.53	Artemisia alcohol	0.18	Champhore	19.05	T rans β-ocimene	93.2	Champhore	20.01	T rans β-ocimene	5.27
11	Champhore	17.89	T rans β-ocimene	0.67	Trans-Sabinene hydrate	1.78	Trans-Sabinene hydrate	0.56	Borneol	3.65	Champhore	17.89	Borneol	4.35	Champhore	24.67
12	Borneol	3.95	Champhore	28.76	T rans β-ocimene	4.21	T rans β-ocimene	6.32	Myrtenal	2.35	Borneol	53.9	Myrtenal	1.54	Borneol	5.54
13	Myrtenal	2.49	Borneol	0.22	Champhore	18.57	Champhore	22.11	Myrtenol	0.81	Myrtenal	92.4	Myrtenol	0.46	Myrtenal	2.31
14	Myrtenol	1.05	Terpinene-4-ol	6.81	Borneol	0.45	Borneol	0.35	Trans-carveol	0.68	Myrtenol	1.05	Trans-carveol	0.76	Myrtenol	1.49
15	Trans-carveol	0.73	Myrtenal	2.11	Terpinene-4-ol	2.99	Terpinene-4-ol	1.24	Cis-carveol	4.08	Trans-carveol	0.73	Cis-carveol	1.52	Trans-carveol	0.49
16	Cis-carveol	3.27	Myrtenol	1.01	Myrtenal	1.44	Myrtenal	2.22	Eugenol	4.88	Cis-carveol	3.27	Eugenol	1.00	Cis-carveol	2.63
17	Eugenol	2.87	Trans-carveol	4.24	Myrtenol	0.65	Myrtenol	0.32	Benzyle 2-methyl butyrate	1.59	Eugenol	2.87	Benzyle 2-methyl butyrate	0.76	Eugenol	2.12
18	Benzyle 2-methyl butyrate	2.02	Cis-carveol	1.65	Trans-carveol	1.88	Trans-carveol	0.33	Tranc- Caryophyllene	7.55	Benzyle 2-methyl butyrate	2.02	Tranc-Caryophylle ne	3.02	Benzyle 2-methyl butyrate	0.76
19	Tranc-Caryophyllene	7.86	Eugenol	4.21	Cis-carveol	1.05	Cis-carveol	3.22	β- farnesene	7.90	Tranc-Caryophyllene	7.86	β-farnesene	5.47	Tranc-Caryophyllene	4.12
20	β- farnesene	9.22	Benzyle 2-methyl butyrate	5.51	Eugenol	6.43	Eugenol	5.32	β- Selinene	0.89	β- farnesene	9.22	β- Selinene	0.83	β- farnesene	4.23
21	β- Selinene	1.01	Tranc-Caryophyllene	11.33	Benzyle 2-methyl butyrate	7.56	Benzyle 2-methyl butyrate	4.15	Ledenoxid	0.66	β- Selinene	1.01	Ledenoxid	-	β- Selinene	0.83
22	Ledenoxid	0.83	β- farnesene	5.56	Tranc-Caryophyllene	9.91	Tranc-Caryophyllene	11.91	-	-	Ledenoxid	0.83	-	-	Ledenoxid	-
23	-	-	β- Selinene	1.23	β- farnesene	3.05	β- farnesene	5.56	-	-	-	-	-	-	-	-
24	-	-	-		β- Selinene	1.23	β- Selinene	2.20	-	-	-	-	-	-	-	-
Total	-	79.13	-	99.73	-	99.4	-	99.69	-	81.6	-	78.15	-	59.59	-	70.22

F_1= 100% R.D. of chemical fertilizers, F_2=50% R.D. of chemical fertilizer and 50% organic fertilizer, F_2= 100% organic fertilizer (15m^3 / feddan of compos

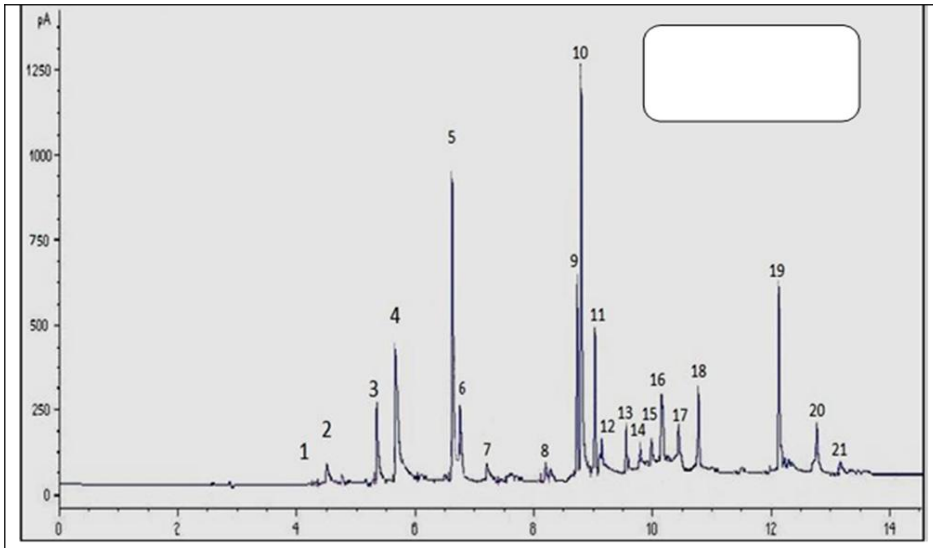

Fig. (1) G.L.C. of artemisia essential oil composition from 30*30+F_2 treatment during the 2nd cut and 2nd season 2020-2021

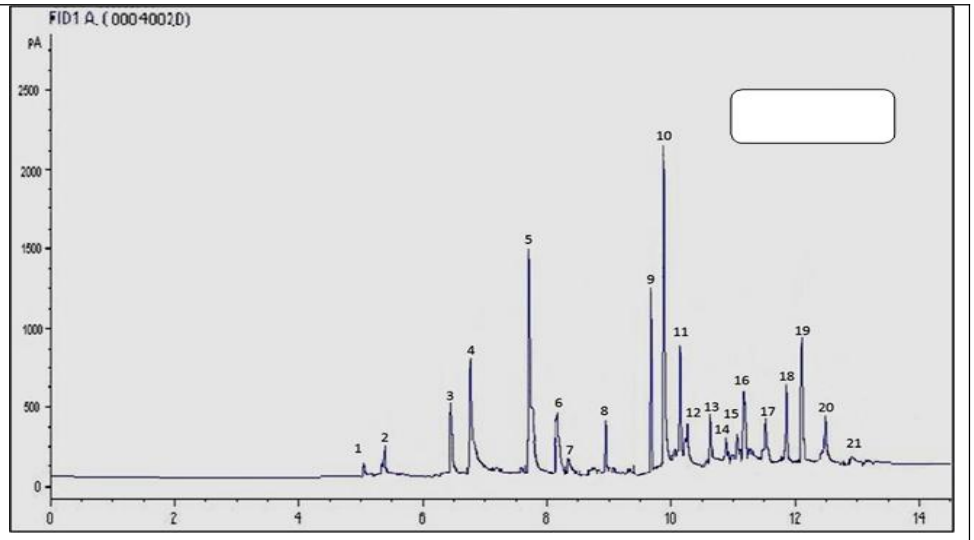

Fig. (2) G.L.C. of artemisia essential oil composition from 30*30+F_3 treatment during the 2nd cut and 2nd season 2020-2021

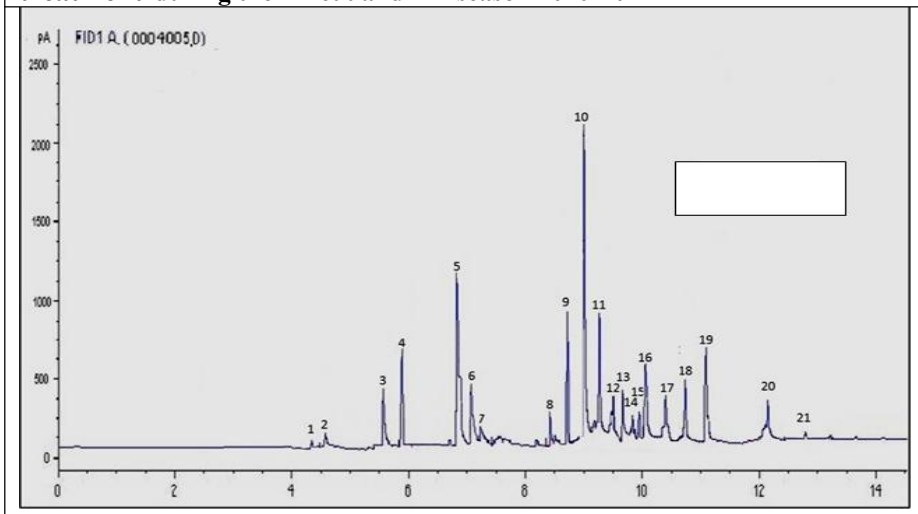

Fig. (3) G.L.C. of artemisia essential oil composition from 40*40+F_2 treatment during the 2nd cut and 2nd season 2020-2021

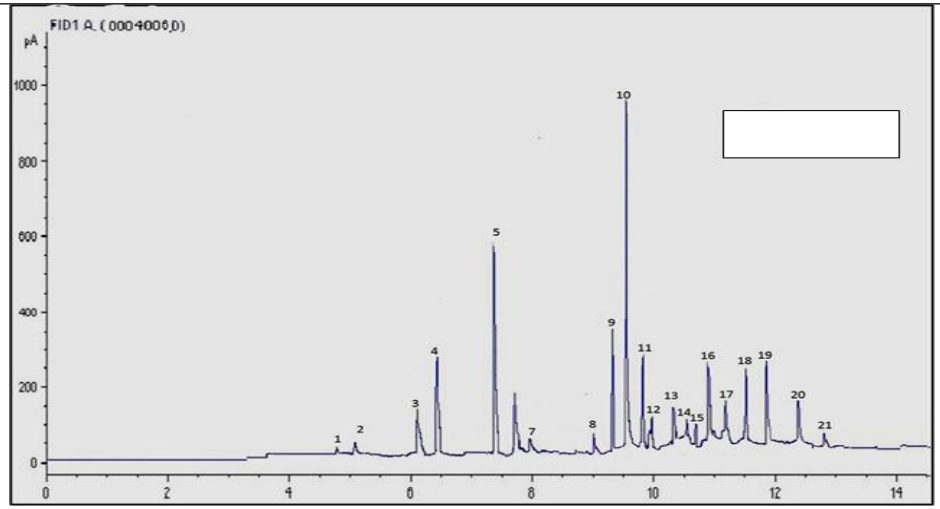

Fig. (4) G.L.C. of artemisia essential oil composition from 40*40+F_3 treatment during the 2nd cut and 2nd season 2020-2021

F_1= 100% R.D. of chemical fertilizers, F_2=50% R.D. of chemical fertilizer and 50% organic fertilizer, F_2= 100% organic fertilizer (15m^3 / feddan of compost

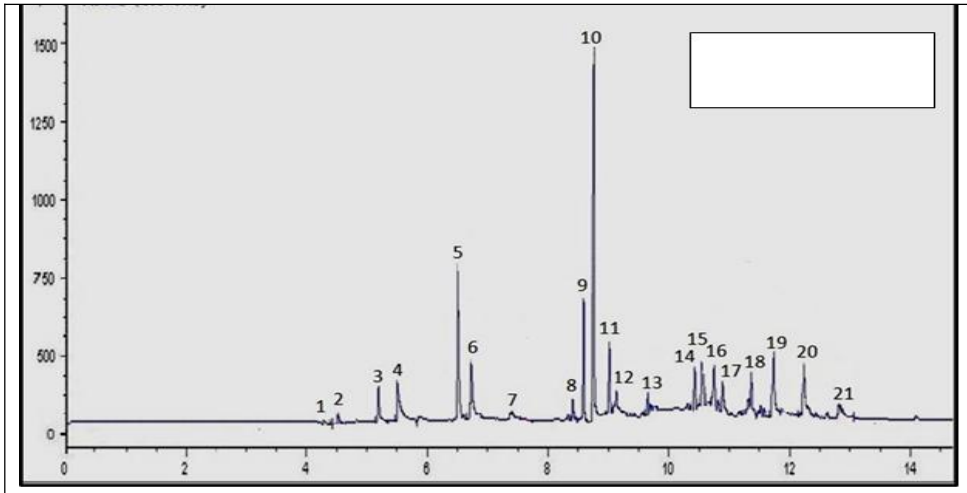

Fig. (5) G.L.C. of artemisia essential oil composition from 50*50+F_2 treatment during the 2nd cut and 2nd season 2020-2021

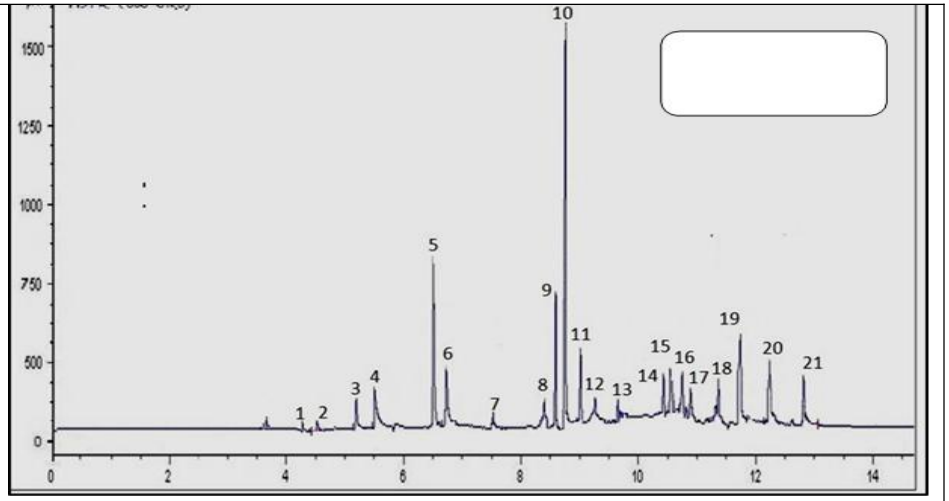

Fig. (6) G.L.C. of artemisia essential oil composition from 50*50+F_3treatment during the 2nd cut and 2nd season 2020-2021

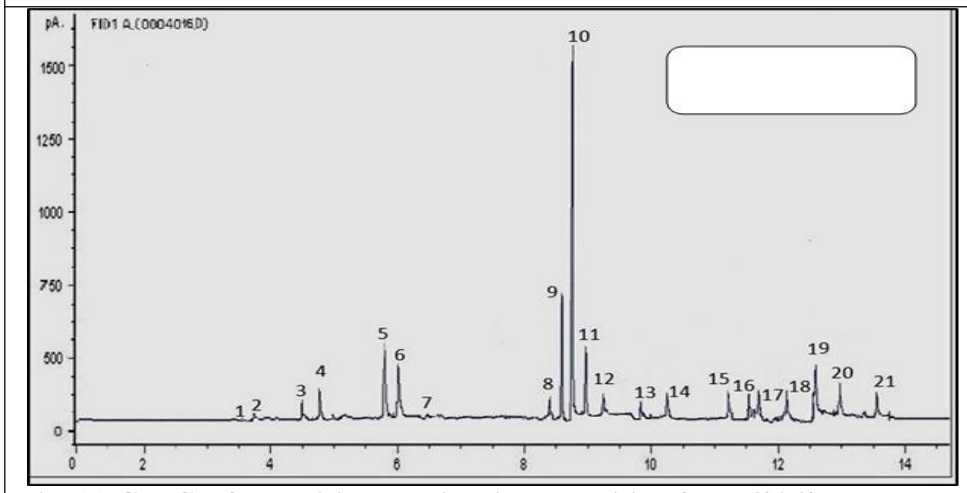

Fig. (7) G.L.C. of artemisia essential oil composition from 60*60+F_2 treatment during the 2nd cut and 2nd season 2020-2021

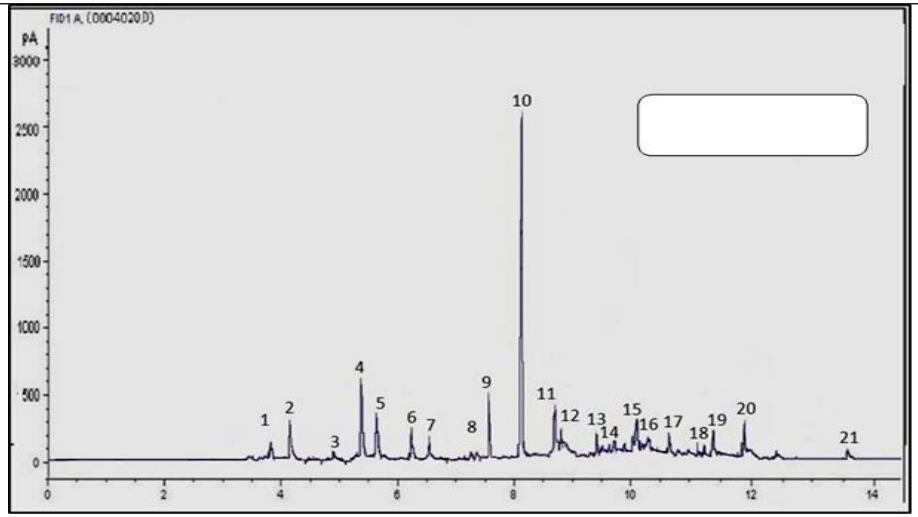

Fig. (8) G.L.C. of artemisia essential oil composition from 60*60+F_3treatment during the 2nd cut and 2nd season 2020-2021

F_1= 100% R.D. of chemical fertilizers, F_2=50% R.D. of chemical fertilizer and 50% organic fertilizer, F_2= 100% organic fertilizer (15m^3 / feddan of compost

The combined treatment between planting distances (30*30 cm) and F_3 recorded the highest values of borneol (28.76%). The maximum values of myrtenal % (22.11%) of *Artemisia annua* L. were gained by the combined treatment planting distances (40*40 cm) and F_3. The major components were 1,8 cineole ρ -pinene and α pinene, camphor, borneol β-caryophyllene.

6. Impact of planting distances and fertilization treatments and their combination on Artemisinin %.

Data in Table (13) and Figs. (from 9,10,11,12,13,14 and 15) declared that the mean values of artemisinin % increased with combination treatments between planting distances and fertilization treatments of artemisinin of . dry leaves. However, the highest value of artemisinin percentage (1.4 %) was scored by (60*60) planting distance with F_2 50% chemical fertilization +50% organic fertilization. Moerover, the combined treatment between (40*40) with F_3 100% organic fertilization as it gave (1.36%) ranked the second values. Additionally, The third value was recorded by combined treatment between (50*50) with F_3 (1.20%), against to lowest values of artemisinin % (0.82%) by combined treatment between (30*30) with F_2.

Table (13) Effect of the combined treatment between planting distances and fertilizations treatments on artemisinin percentage of *Artemisia Annua* L. plant during the second season 2018-2019

No	Treatments	Artemisinin percentage (%)
1	(30*30) +F2	0.82
2	(30*30) +F3	0.88
3	(40*40) +F2	0.98
4	(40*40) +F3	1.36
5	(50*50) +F2	0.95
6	(50*50) +F3	1.20
7	(60*60) +F2	1.4

F_1= 100% R.D. of chemical fertilizers, F_2=50% R.D. of chemical fertilizer and 50% organic fertilizer, F_2= 100% organic fertilizer (15m^3 / feddan of compost

In this respect, **El-Ghawwas *et.al.* (2011)** on (*Artemisia annua*) found that, the widest distance (60 x 40cm)increased the highest artemisinin content in the leaves, **Prabhakar *et.al.* (2011)** on (*Artemisia annua*) and **Choudhari and Choudhary (2013)** on (*Artemisia annua*) found that, 45×60 cm distance gave a higher artemisinin yield.

Moreover**, Yeboah *et.al.* (2012)** on (*Artemisia annua*) found that, 4 t/ha poultry manure gave the highest artemisinin yield, **Heikal (2017)** on(*Artemisia annua*), **Mohamed *et.al.* (2021)** on *Trachyspermum ammi* L.

Conclusively, it is preferable to apply the planting distance(40*40 cm) and F_3 100% organic fertilizers .for enhancing Consequently, it is preferable applying the planting distance(40*40 cm) and F3 for enhancing all studied traits of artemisia plant.

F_1= 100% R.D. of chemical fertilizers, F_2=50% R.D. of chemical fertilizer and 50% organic fertilizer, F_2= 100% organic fertilizer (15m^3 / feddan of compos

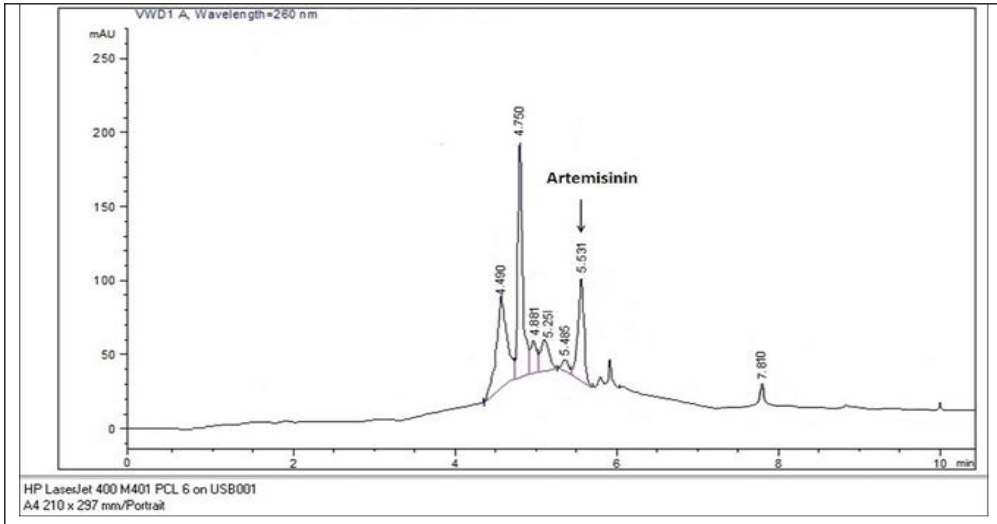

Fig. (9) Effect of 30*30+F_2 treatment on artemisinin percentage of *Artemisia Annua* L. plant during 2nd cuts and the 2nd season 2020-2021 .

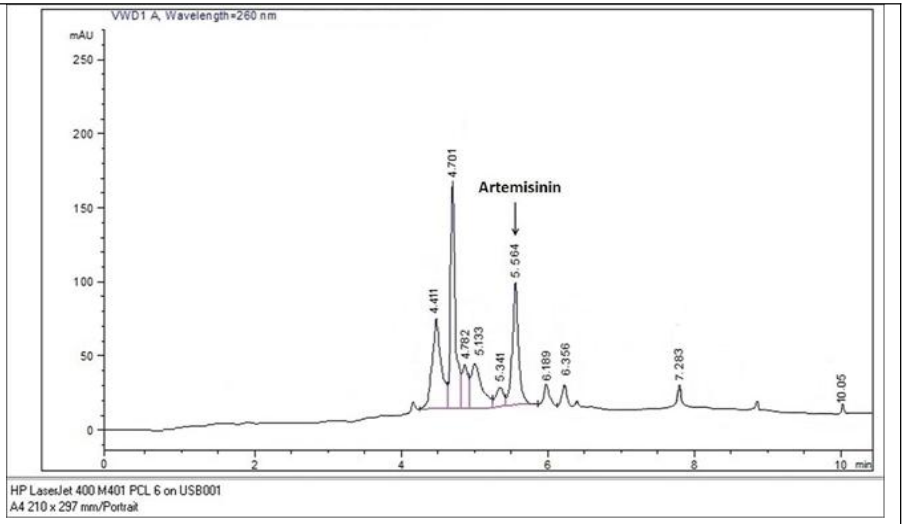

Fig. (10) Effect of 30*30+F_3 treatment on artemisinin percentage of *Artemisia Annua* L. plant during 2nd cuts and the 2nd season 2020-2021 .

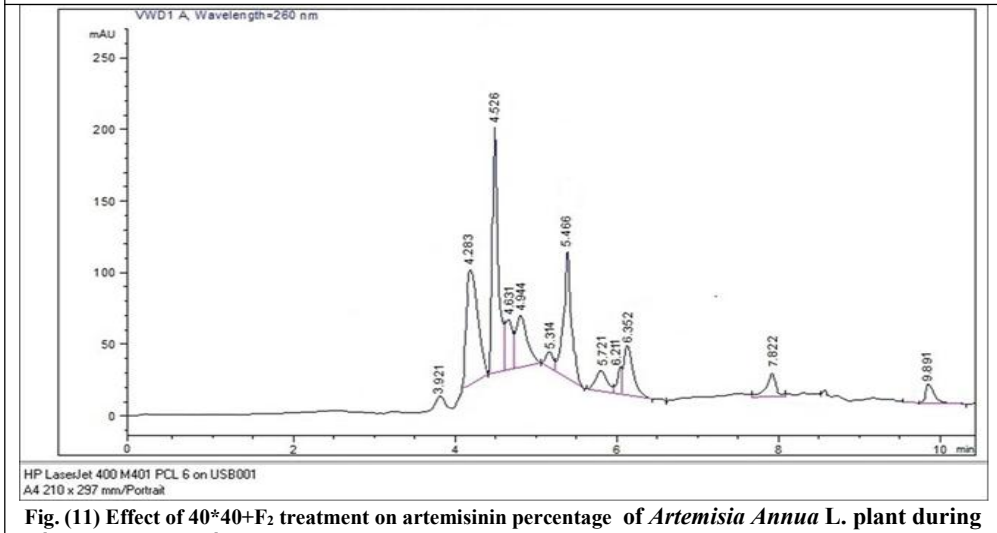

Fig. (11) Effect of 40*40+F_2 treatment on artemisinin percentage of *Artemisia Annua* L. plant during 2nd cuts and the 2nd season 2020-2021

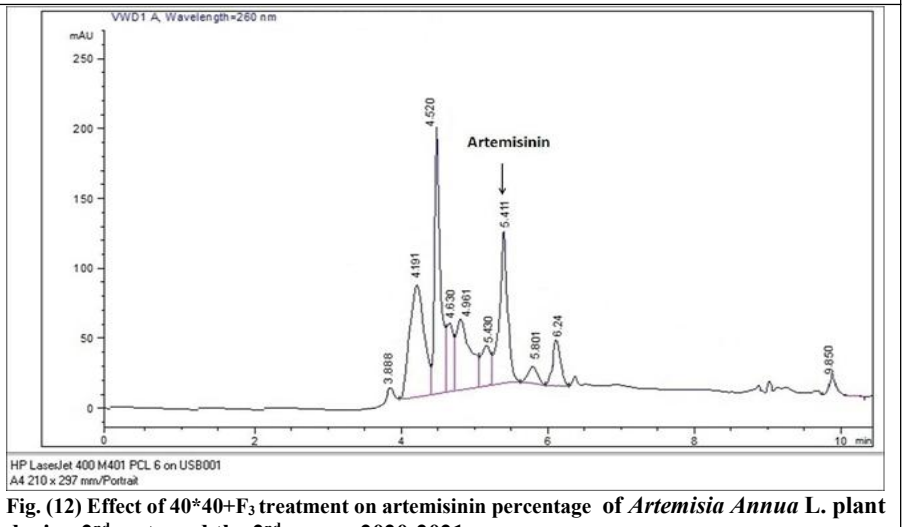

Fig. (12) Effect of 40*40+F_3 treatment on artemisinin percentage of *Artemisia Annua* L. plant during 2nd cuts and the 2nd season 2020-2021 .

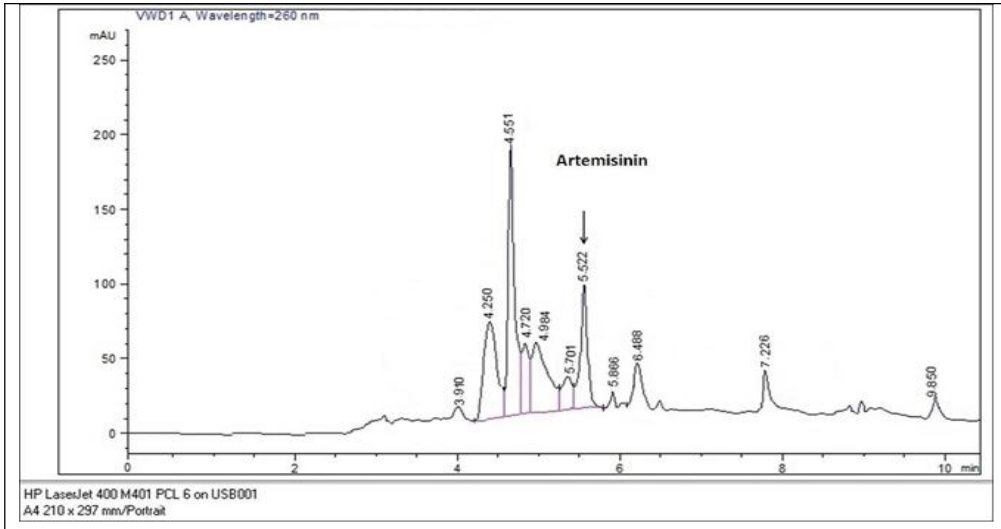

Fig. (13) Effect of 50*50+F_2 treatment on artemisinin percentage of *Artemisia Annua* L. plant during 2nd cuts and the 2nd season 2020-2021

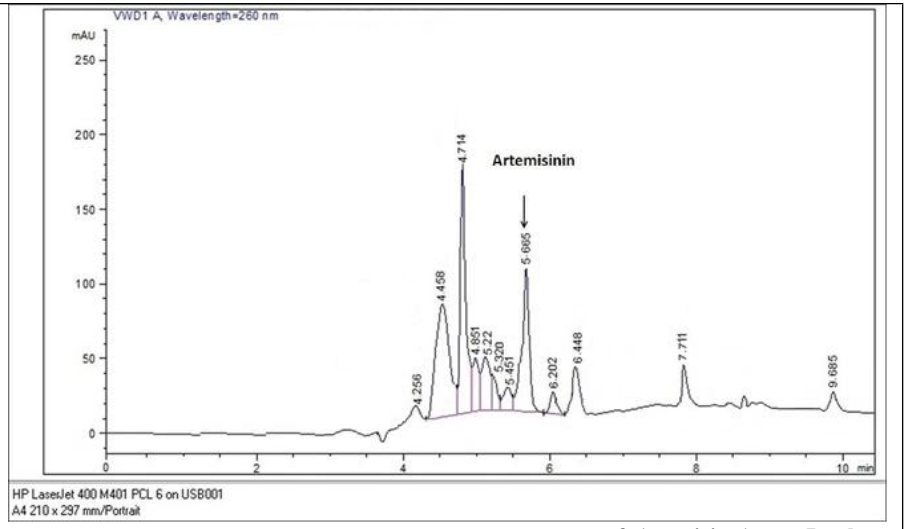

Fig. (14) Effect of 50*50+F_3 treatment on artemisinin percentage of *Artemisia Annua* L. plant during 2nd cuts and the 2nd season 2020-2021 .

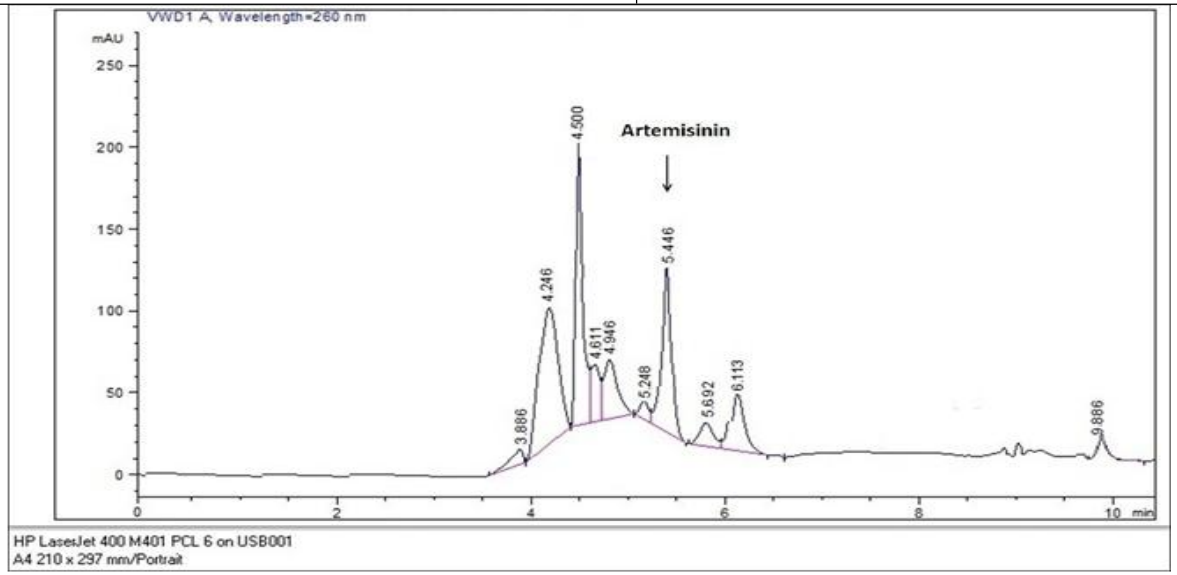

Fig. (15) Effect of 60*60+F_2 treatment on artemisinin percentage of *Artemisia Annua* L. plant during 2nd cuts and the 2nd season 2020-2021

F_1= 100% R.D. of chemical fertilizers, F_2=50% R.D. of chemical fertilizer and 50% organic fertilizer, F_2= 100% organic fertilizer (15m^3 / feddan of compost

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تأثير مسافات الزراعة في وجود معاملات التسميد الكيميائي والعضوي على النمو والزيوت العطرية ومحتوى مادة الأرتيميزينين والمكونات الكيميائية لنبات الارتيمزيا انوا ..Artemisia annua L

الارتيمزيا انوا .*Artemisia annua* L هو نبات حولى عطري يتبع العائلة المركبة (Asteraceae) مدرج في دستور الأدوية الصيني ، كعلاج لأمراض مختلفة .تحتوي الاوراق والعشب على زيوت عطرية متطايرة و sesquiterpenesغير متطايرة تستخدم في دستور الأدوية .وأهم مادة كسيسكيتيربين هي مادة الأرتيميزينين ومشتقاتها التي تستخدم كعلاج للملاريا .تم إجراء هذا البحث في مزرعة الزينة التابعة لقسم البساتين بكلية الزراعة جامعة بنها مصر خلال الموسمين المتتاليين 2020/2019 و 2021/2020 لدراسة تأثير مسافات الزراعة ومعاملات التسميد على النمو الخضري والمكونات الكيميائية وزيت الزيت .نبات الارتيمزيا انوا .أظهرت النتائج في كل من الحشتين وخلال موسمي الدراسة أن قيم النمو الخضري و القياسات الجزرية سجلت اعلى القيم من خلال معاملة مسافات زراعة (40 * 40 سم) و F_3 سماد عضوي 100٪ .(إلى جانب ذلك ، كان للتفاعل بين مسافات الزراعة ومعاملات التسميد تأثير معنوي على التركيبات الكيميائية خاصة مسافة الزراعة (40 * 40 سم) و F_3 في الحشتين وفي كلا الموسمين .بشكل عام ، سجلت أعلى قيم لنسبة الزيت العطري في الأوراق عن طريق معاملة التفاعل بين مسافة الزراعة (40 * 40 سم) و F_3 تم تحديد مكونات الزيت العطري في .Artemisia annua L المنتجة من 23 مكونًا .ومن ثم ، كانت المكونات الرئيسية هي β- champhore, cis-Sabinene hydrate, T rans ocimene, artemisia ketone, borneol, tranc- Caryophyllene, myrtenal and β- Selinene

علاوة على ذلك ، تم تسجيل أعلى قيمة لنسبة مادة الأرتيميزينين (1.4٪) بواسطة (60 * 60) مع F_2. وبالتالي ، يفضل تطبيق مسافة الزراعة (40 * 40 سم) و F_3 لتعزيز النمو والزيوت الطيارة ومحتوى الأرتيميزينين والمكونات الكيميائية ***Artemisia annua* L.لنبات**

الكلمات الداله:الارتيميزيا انوا- محتوى الارتيميسين- محتوى الزيت- المحتوى الكيميائي- النمو- التسميد