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Response of *Thymus vulgaris* L. Plant to Planting Distances and Fertilization Treatments

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ABSTRACT

This investigation was carried out during the 2017 and 2018 seasons, at the Experimental Farm of Horticulture Department, Faculty of Agriculture, Benha University, Egyp for studying the effect of different planting distances (20*20 and 30*30cm), and bio-fertilizers (PGRB), chemical fertilizers (NPK) and micronutrients (Zn, Fe, and Mn) on thyme plants. Results show that in each of the two cuts and the studied seasons, the maximum vegetative growth values were determined by using the combination between the planting spacing (30*30 cm), and F2 (PGRB). Hence, this combination enhanced the chemical compositions compared with most other treatments at both seasons. In addition, the essential oil percentage of thyme plant was increased by using the combined treatment of planting distances (30*30 cm) and F2. GLC analysis of thyme included 12 compounds were identified, and the main component was β-Cymene. Consequently, it is preferable to use the planting distance (30*30cm), and F2 (PGRB) for improving all studied parameters of thyme plant.

Keywords: *Thymus vulgaris*, planting distance, bio-fertilizers (PGRB), NPK and micronutrients, and Volatile 0il

INTRODUCTION

Thyme, (*Thymus vulgaris* L.) belongs to the family Lamiaceae. Thyme is considered an important edible wild plant studied for importance in the pharmaceutical, food, and cosmetic industry. However, thyme is a rich source of minerals, vitamins, and phytonutrients. But is mainly composed of flavonoids and antioxidants. So, it is providing high antibacterial properties and antioxidants (Mokhtari *et al*. 2023). It has many therapeutic effects because of containing thymol and carvacrol in its essential oil antioxidant, antineoplastic actions, and anti-inflammatory (Hammoudi *et al*., 2022).

The planting spacing is a factor that affects the nutrient absorption in water and the photosynthesis process, which led to the growth of plants. Planting at a specific distance is highly related to nutrition and sunlight which are environmental parameters affecting biomass and productivity. Also, the wider the planting distance, the more circulation brings nutrients to the plant which increases growth (Aslin *et al*. 2019). El-Ghawwas *et al*. 2011) on *Artemisia annua* illustrated that the planting distance (60 x 40cm) improved the vegetative growth of the plant. Tadesse (2019) on *Lavandula anguistifolia*, and *Rosmarinus officinalis*, and (Mengistu *et al*. 2021) on *Nigella sativa* reported the important of planting spacing on the growth and productivity of these plants.

Biofertilizers are eco-friendly and are proven to be an economical and effective alternative of chemical fertilizers with less energy and input (Sahu *et al*. 2012). Bio-fertilizers (microbial-based fertilizers) are considered crucial components of sustainable agriculture with long-lasting effects on soil fertility (Bargaz *et al*., 2018; Singh *et al*., 2019). On the other hand, chemical fertilizers are indispensable material input in modern agricultural production. An increase in chemical fertilizer input helps boost crop productivity and significantly contributes to global food security. In this context, Mohamed and Ghatas (2016) declared that using EM at 30 ml/plant + NPK at 75% or 100% of NPK maximized volatile oil composition in for leaves and flowers of violet (Xing Ji et al., 2023). Iron (Fe), zinc (Zn), and manganese (Mn) are micronutrients that are necessary for plant growth and development. foliar application of micronutrients on crop improves their ability to absorb nutrients and photosynthesis as it plays vital role in various biochemical processes (Mounika *et al*., 2018). Therefore, the aim of this study was to evaluate the effect of planting distances and fertilization treatments besides the combinations between them on the growth and essential oil constituents of the thyme plant.

MATERIALS AND METHODS

This study was carried out during the 2017 and 2018 seasons at the Experimental Farm of Hortic. Department, Fac. of Agric., Benha University., Egypt to study the effect of different plant distances (20*20 and 30*30cm), bio-fertilizers (PGRB), Chemical fertilizers (NPK) and Micronutrients (Zn, Fe and Mn) on vegetative growth characters, yield and essential oil compositions and chemical constituents of *Thymus vulgaris* L. Plant.

Cutting was obtained from Floriculture Farm, Hortic. Department, Faculty of Agric., Benha University, in the two seasons. The cuttings (5-7 cm) were planted in polyethylene bags as a mixture of (clay: sand, 1:1 v:v) on December 5th

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after seedlings were planted on March 21[st] in two seasons. Chemical and mechanical analyses of the experimental soils are recorded in Table (1). Mechanical analysis was carried out according to Jackson (1973), whereas chemical analysis was carried out according to Black *et al.* (1982).

Table 1. Chemical analysis and mechanical properties of the experimental soil

Parameters	Values		Parameters	Values	
A. Mechanical properties			B. Chemical analysis		
	(2017)	(2018)		(2017)	(2018)
Coarse sand	7.12 %	6.55 %	Organic matter	1.80%	1.75 %
Fine sand	11.88 %	12.99 %	$CaCO_3$	1.09 %	1.17 %
Silt	24.77 %	26.24 %	Available nitrogen	0.88 %	0.96 %
Clay	56.23 %	54.22 %	Available phosphorus	0.25%	0.33 %
Textural class	Clay loam	Clay loam	Available potassium	0.62 %	0.69%
			pH	7.44	7.66
			EC (dS/m)	0.86	0.84

Experimental layout

This experiment was laid as a factorial experiment in Randomized Complete Block Design (RCBD) with two factors, the first was the two planting distances treatments with nine fertilization treatments. All 18 treatments were replicated three times and each replicate contained three plots area and each plot (1*1m) contained of 6 plants with spacing (20*20cm), and 4 plants with spacing (30*30cm). The plants received normal agricultural practices whenever needed.

The second factor was fertilization treatments: The plants were treated with bio-fertilizer treatment (PGRB) after a month from planting. (PGRB) were received from the cultural collocation of Agriculture, Microbiology Department National Research Centre, Egypt.

1. A balance NPK fertilizer (20:20:20) was applied in three doses, the first addition was after two weeks from planting and the second added after a month from the first addition and the third addition was after a month from the second addition.

Micronutrients of zinc, iron, and manganese were applied as a foliar spray with the same time of NPK addition, throughout the period of growth individually as zinc at a rate of 75 and 100 ppm, manganese at a rate of 75 and 100 ppm and iron at a rate of 100 and 150 ppm.

Harvesting time

During both seasons, thyme plants were harvested throughout the two cuts in each harvest. The first cut was in 30[th]June. While the second cut was in 30[th] September of both seasons 2017 & 2018.

Data recorded

Vegetative growth

Plant height (cm), herb fresh weight/plant (g), herb dry weight/plant (g), herb fresh weight/plant (kg/fed) and number of branches were determined at the end of the experiment

Chemical composition

Chlorophyll (A and B) was determined calorimetrically in leaves of thyme according to **A.O.A.C (1990)** and calculated as mg/100g of fresh weight.

Nitrogen, phosphorus, potassium and total carbohydrates were tested in thyme according to Horneck and Miller (1998), Hucker and Catroux (1980), Horneck and Hanson (1998), and Herbert et al. (1971). Micronutrients Fe, Mn, and Zn (%) were tested in the samples by atomic absorption as described by (Chapman and Paratt, 1961).

-Essential oils character

Essential oil (%): was determined by distillation of volatile oil for three hours to extract the essential oils according to British Pharmacopeia (1963).

GLC (analysis of the volatile oil components) according to Bunzen *et al.* (1969) and Hoftman (1967).

Statistical analysis

The means of each obtained results from the studied factors were analyzed variance (ANOVA) as factorial experiments in a complete randomized block design). The differences between the mean values of various treatments were compared by using the least significant differences (L. S. D.) at 0.05 %, as stated by Snedecor and Cochran (1989) using MSTAT-C statistical software package.

RESULTS AND DISCUSSION

Effects of planting distances and fertilizations treatments and their combinations on vegetative growth of *Thymus vulgaris*, L. plants during 2017 & 2018 seasons.

Tables (2, 3 and 4) illustrated that all vegetative growth such as plant height (cm), number of branches per plant, herb fresh and dry weight (g/plant) and herb fresh weight (Kg/ Fed) of thyme plant were increased by planting at a distance of (30*30 cm) in the two cuts and both seasons. As for fertilizer treatments, data showed that of parameters mentioned were highly affected by all fertilizer's treatments in two cuts and in both seasons. The highest significant parameters were recorded with applying F2 (PGRB), followed by F3 (NPK). However, the highest values were recognized by using the combination treatment between planting distances (30*30 cm) and F2 (PGRB), followed descending by the combination treatment of planting distances (20*20cm) and F2 in the two cuts and seasons .By addition, the abovementioned results are met with those recorded by Fathi *et al.* (2022) on sweet basil, using a mixture of bio-fertilizers, the yield was improved by 29.88%., (Chandra *et al.* 2022) on (*Phyllanthus amarus*),with use of bio-fertilizers, the combined application of Bacteria led to higher fresh and dry weight. In addition, (Punetha *et al.* 2022) on *Thymus vulgaris* L. using of a wider row spacing (40 cm) produced higher yield than in the case of (30 cm). Furthermore, Nurzyńska-Wierdak *et al.* (2023) on *Melissa officinalis* illustrated that planting distance (40 x 40cm) improved the vegetative growth, than (30 x 30cm). Mohamed *et al.* (2023) on (*Artemisia annua*), obtained the best result by applying the planting spacing(40*40cm), to improve the vegetative growth.

Table 2. Effects of planting distances, fertilizations treatments andtheir interaction treatments on plant height (cm) and number of branches/plant of *Thymus vulgaris* L. plants within 2017and 2018seasons.

Parameters	**Plant height (cm)**						**Number of branches /plant**					
Cutting	**1st cut**			**2nd cut**			**1st cut**			**2nd cut**		
Plant distance (A)	**Plant distance (A)**			**Plant distance (A)**			**Plant distance (A)**			**Plant distance (A)**		
Fertilization Treatments(B)	**20*20**	**30*30**	**Mean**	**20*20**	**30*30**	**Mean**	**20*20**	**30*30**	**Mean**	**20*20**	**30*30**	**Mean**
1st season												
F_1	18.53	17.03	17.78	22.600	21.100	21.850	5.033	5.767	5.400	8.733	9.300	9.017
F_2	28.17	26.33	27.25	33.600	31.867	32.733	8.667	10.033	9.350	13.300	16.267	14.783
F_3	27.13	24.00	25.57	30.667	29.533	30.100	8.000	9.467	8.733	12.233	15.033	13.633
F_4	23.03	21.03	22.03	28.500	27.033	27.767	7.033	7.633	7.333	9.767	11.400	10.583
F_5	22.67	20.50	21.58	27.567	26.833	27.200	6.567	7.300	6.933	9.267	10.867	10.067
F_6	20.00	18.00	19.00	24.100	22.833	23.467	5.733	6.233	5.983	8.667	9.700	9.183
F_7	20.83	19.20	20.02	24.800	23.233	24.017	6.333	6.733	6.533	9.067	10.267	9.667
F_8	24.83	22.03	23.43	29.100	27.933	28.517	7.167	8.033	7.600	10.300	12.767	11.533
F_9	26.20	22.83	24.52	29.533	28.433	28.983	7.633	8.533	8.083	11.267	13.633	12.450
Mean	23.48	21.22		27.830	26.533		6.907	7.748		10.289	12.137	
L.S.D at 0.05 for	A=0.321 B= 0.681 AXB=0.963			A=0.396 B=0.840 AXB=1.188			A= 0.171 B= 0.362 AXB=0.511			A= 0.131 B= 0.278 AXB=0.393		
2nd season												
F_1	20.067	17.633	18.850	25.567	23.533	24.550	5.833	6.033	5.933	8.600	9.633	9.117
F_2	29.533	27.500	28.517	35.167	33.83	34.500	9.667	10.500	10.083	14.067	17.000	15.533
F_3	28.033	26.100	27.067	32.667	31.533	32.100	8.967	9.733	9.350	13.033	16.133	14.583
F_4	24.300	22.100	23.200	29.467	29.167	29.317	7.233	7.800	7.517	10.767	12.967	11.867
F_5	23.267	21.433	22.350	28.133	28.633	28.383	6.833	7.433	7.133	9.967	12.200	11.083
F_6	21.200	19.233	20.217	26.733	25.333	26.033	6.033	6.633	6.333	8.767	9.967	9.367
F_7	22.533	20.700	21.617	27.100	25.333	26.517	6.167	7.033	6.600	9.567	10.900	10.233
F_8	25.867	23.967	24.917	30.367	29.800	30.083	7.600	8.467	8.033	11.533	14.367	12.950
F_9	27.000	25.100	26.050	31.367	30.733	31.050	8.233	9.133	8.683	12.300	15.333	13.817
Mean	24.644	22.641		29.619	28.722		7.396	8.085		10.956	13.167	
L.S.D at 0.05 for	A= 0.312 B= 0.662 AXB= 0.936			A= 0.402 B= 0.853 AXB=1.206			A= 0.138 B= 0.292 AXB= 0.413			A= 0.199 B= 0.423 AXB= 0.598		

F_1: control, F_2: PGRB, F_3: NPK, F_4: Fe at 150 ppm, F_5: Fe at 100 ppm, F_6: Zn at 100 ppm, F_7: Zn at 75 ppm, F_8: Mn at 100 ppm, F_9: Mn at 75 ppm.

Table 3. Effects of planting distances, fertilization treatments and their interaction treatments on herb fresh and dry weights (g/ plant) of *Thymus vulgaris* L. plants during 2017and 2018 seasons.

Parameters	**Herb fresh weight (g/ plant)**						**Herb dry weight (g/ plant)**					
Cutting	**1st cut**			**2nd cut**			**1st cut**			**2nd cut**		
Plant distance(A)	**Plant distance (A)**			**Plant distance (A)**			**Plant distance (A)**			**Plant distance (A)**		
Fertilization Treatments(B)	**20*20**	**30*30**	**Mean**	**20*20**	**30*30**	**Men**	**20*20**	**30*30**	**Mean**	**20*20**	**30*30**	**Mean**
1st season												
F_1	38.633	42.833	40.733	54.333	65.533	59.933	12.800	14.233	13.517	18.100	21.833	19.967
F_2	64.767	72.433	68.600	92.600	107.933	100.267	21.567	24.133	22.850	30.833	35.967	33.400
F_3	58.500	63.000	60.750	84.600	95.200	89.900	19.067	21.100	20.083	28.200	32.100	30.150
F_4	47.233	49.633	48.433	68.767	78.567	73.667	15.733	16.533	16.133	22.900	26.167	24.533
F_5	45.767	48.933	47.350	65.467	75.600	70.533	15.233	16.333	15.783	21.833	25.200	23.517
F_6	40.533	45.600	43.067	61.667	70.300	65.983	13.500	15.200	14.350	20.567	23.433	22.000
F_7	43.100	47.467	45.283	63.700	73.133	68.417	14.367	15.833	15.100	21.200	24.367	22.783
F_8	49.233	54.400	51.817	75.233	84.433	79.833	16.400	18.133	17.267	25.100	28.133	26.617
F_9	53.267	57.133	55.200	79.433	88.933	84.183	17.567	19.033	18.300	26.467	29.633	28.050
Mean	49.004	53.493		71.756	82.181		16.248	17.837		23.911	27.426	
L.S.D at 0.05 for	A= 0.905 B= 1.920 AXB= 2.716			A= 0.935 B= 1.983 AXB=2.804			A= 0.341 B=0.722 AXB=1.022			A=0.291 B=0.616 AXB=0.872		
2nd season												
F_1	40.133	45.567	42.850	69.433	68.267	68.850	13.367	15.200	14.283	23.167	22.767	22.967
F_2	74.633	81.300	77.967	112.800	128.200	120.500	24.867	27.067	25.967	37.633	42.733	40.183
F_3	68.567	75.033	71.800	95.567	99.467	97.517	22.800	25.000	23.900	31.867	33.133	32.500
F_4	51.967	65.767	58.867	90.467	81.633	86.050	17.333	21.900	19.617	30.167	27.033	28.600
F_5	49.233	61.333	55.283	77.233	77.533	77.383	16.433	20.400	18.417	25.767	25.833	25.800
F_6	42.733	50.967	46.850	70.133	72.100	71.117	14.200	17.000	15.600	23.467	24.000	23.733
F_7	47.400	57.000	52.200	73.533	74.933	74.233	15.767	19.033	17.400	24.500	24.967	24.733
F_8	56.300	68.033	62.167	81.567	86.033	83.800	18.767	22.700	20.733	27.200	28.700	27.950
F_9	62.767	71.300	67.033	86.467	90.533	88.500	20.933	23.800	22.367	29.067	30.200	29.633
Mean	54.859	64.033		84.133	86.522		18.274	21.344		28.093	28.819	
L.S.D at 0.05 for	A= 1.124 B= 2.38 AXB=3.373			A= 1.405 B= 2.981 AXB=4.216			A=0.376 B= 0.797 AXB=1.127			A= 0.472 B= 1.002 AXB=1.417		

F_1: control, F_2: PGRB, F_3: NPK, F_4: Fe at 150 ppm, F_5: Fe at 100 ppm, F_6: Zn at 100 ppm, F_7: Zn at 75 ppm, F_8: Mn at 100 ppm, F_9: Mn at 75 ppm.

Table 4. Effects of planting distances, fertilization treatments and their interaction treatments on herb fresh weight (Kg/ Fed) of *Thymus vulgaris* L. plants during 2017and 2018 seasons.

Parameters	Herb fresh weight (Kg/ Fed)					
Cutting	1st cut			2nd cut		
Plant distance(A)	Plant distance (A)			Plant distance (A)		
Fertilization Treatments(B)	20*20	30*30	Mean	20*20	30*30	Mean
			1st season			
F_1	0.966	1.071	1.018	1.352	1.639	1.495
F_2	1.619	1.811	1.715	2.315	2.699	2.507
F_3	1.463	1.575	1.519	2.115	2.380	2.248
F_4	1.181	1.241	1.211	1.719	1.964	1.842
F_5	1.144	1.223	1.184	1.637	1.890	1.764
F_6	1.014	1.140	1.077	1.542	1.758	1.650
F_7	1.078	1.187	1.132	1.593	1.828	1.711
F_8	1.231	1.360	1.296	1.881	2.111	1.996
F_9	1.332	1.429	1.380	1.986	2.223	2.105
Mean	1.225	1.337		1.793	2.055	
L.S.D at 0.05 for	A= 0.025 B= 0.052 AXB= 0.074			A=0.025 B=0.052 AXB=0.074		
			2nd season			
F_1	1.003	1.139	1.071	1.736	1.707	1.721
F_2	1.866	2.033	1.949	2.820	3.205	3.013
F_3	1.714	1.876	1.795	2.389	2.487	2.438
F_4	1.300	1.644	1.472	2.262	2.041	2.151
F_5	1.231	1.534	1.382	1.931	1.939	1.935
F_6	1.068	1.274	1.171	1.753	1.803	1.778
F_7	1.185	1.425	1.305	1.838	1.874	1.856
F_8	1.408	1.701	1.554	2.039	2.151	2.095
F_9	1.569	1.783	1.676	2.162	2.264	2.213
Mean	1.372	1.601		2.103	2.163	
L.S.D at 0.05 for	A= 0.030 B= 0.064 AXB= 0.091			A= 0.035 B= 0.074 AXB=0.105		

F_1: control, F_2: PGRB, F_3: NPK, F_4: Fe at 150 ppm, F_5: Fe at 100 ppm, F_6: Zn at 100 ppm, F_7: Zn at 75 ppm, F_8: Mn at 100 ppm, F_9: Mn at 75 ppm.

Effect of planting distances and fertilizations treatments and their interactions treatments on chemical composition of *Thymus vulgaris*, L. plants within 2017 & 2018 seasons.

Data in Table (5 and 6) indicated that nitrogen, phosphorus, potassium and total carbohydrates (% /plant) of thyme plant were increased by applying planting distances (30*30 cm) in two cuts and seasons. On the other side, data showed that parameters mentioned above was greatly affected by all fertilizer's treatments in both cuts and two seasons. However, the greatest values of P, N, K and total carbohydrates % were obtained by F2 (PGRB), followed by F3 (NPK). The highest values were recorded by using the combination treatment of planting distances (30*30cm) and F2, followed descendingly by the combination treatment of planting distances (20*20cm) and F2 in the two cuts and seasons in most cases. While the lowest values of these parameters obtained from the combination between planting distances (20*20cm) and F1 in two cuts and in the two seasons. Also, the abovementioned results are in harmony with those attained by Yousef *et al.* (2020) on Jewish mallow, stated that using NPK + bio-fertilizer treatment led to increase the concentrations of N, P and K in leaves, Rahimi *et al.* (2020) on *Ocimum basilicum* L. cleared that using organic and biofertilizers had the great effect on phenolic and flavonoid content and nitric acid. In addition, EL-Zawawy *et al.* (2021) on *Calendula officinalis* L., cleared that the biofertilization enhanced all chemical components, carbs, minerals, and oleanolic acid. Moreover, Mohamed *et al.* (2015) they showed that using biofertilizer treatments gave the bes results of chemical compositions of *Ocimum basilicum* L. Also, Mohamed *et al.* (2023) on *Artemisia annua*, found that the best planting distance was 40*40 cm for enhancing the chemical compositions. Also, Nurzyńska-Wierdak *et al.* (2023) on *Melissa officinalis*, illustrated that planting distance (40 x 40cm) improved tannin and flavonoid contents, a better than (30 x 30cm).

Table 5. Effects of planting distances, fertilization treatments and their interaction treatments on nitrogen and phosphorus %/plant of *Thymus vulgaris* L. plants within 2017& 2018 seasons.

Parameters	N (%)						P (%)					
Cutting	1st cut			2nd cut			1st cut			2nd cut		
Plant distance(A)	Plant distance (A)			Plant distance (A)			Plant distance (A)			Plant distance (A)		
Fertilization Treatments(B)	20*20	30*30	Mean	20*20	30*30	Mean	20*20	30*30	Mean	20*20	30*30	Mean
						1st season						
F_1	1.013	1.867	1.440	0.780	1.677	1.228	0.293	0.293	0.293	0.318	0.320	0.319
F_2	2.320	2.870	2.595	2.390	2.120	2.255	0.447	0.550	0.498	1.199	0.701	0.950
F_3	1.487	2.210	1.848	1.977	2.053	2.015	0.413	0.537	0.475	0.614	0.601	0.607
F_4	2.120	2.657	2.388	2.237	2.053	2.145	0.380	0.447	0.413	0.485	0.487	0.486
F_5	1.917	2.217	2.067	2.063	1.883	1.973	0.403	0.483	0.443	0.521	0.501	0.511
F_6	1.153	1.757	1.455	1.263	1.020	1.142	0.323	0.403	0.363	0.423	0.376	0.399
F_7	1.033	2.210	1.622	1.093	1.120	1.107	0.290	0.393	0.342	0.328	0.326	0.327
F_8	1.163	1.990	1.577	1.883	1.857	1.870	0.363	0.440	0.402	0.438	0.414	0.426
F_9	1.957	1.770	1.863	2.083	2.040	2.062	0.347	0.427	0.387	0.426	0.385	0.405
Mean	1.574	2.172		1.752	1.758		0.362	0.441		0.528	0.457	
L.S.D at 0.05 for	A= 0.0004 B=0.0009 AXB=0.0013			A= 0.017 B= 0.037 AXB=0.052			A= 0.0005 B=0.0010 AXB=0.0014			A= 0.0005 B=0.0011 AXB=0.0016		
						2nd season						
F_1	1.507	1.883	1.695	1.757	2.207	1.982	0.303	0.277	0.290	0.388	0.369	0.378
F_2	2.653	2.877	2.765	2.877	2.88	2.880	0.507	0.557	0.532	1.348	0.746	1.047
F_3	2.427	2.660	2.543	2.757	2.877	2.817	0.443	0.547	0.495	0.646	0.633	0.640
F_4	2.207	2.213	2.210	2.653	2.850	2.752	0.427	0.490	0.458	0.572	0.507	0.540
F_5	1.947	2.207	2.077	2.427	2.317	2.372	0.437	0.503	0.470	0.574	0.530	0.552
F_6	1.327	1.767	1.547	1.030	1.990	1.510	0.357	0.417	0.387	0.484	0.405	0.445
F_7	1.327	1.770	1.548	1.737	2.200	1.968	0.313	0.413	0.363	0.396	0.370	0.383
F_8	1.663	1.977	1.820	2.210	2.427	2.318	0.413	0.480	0.447	0.506	0.459	0.483
F_9	2.203	2.207	2.205	2.647	2.430	2.538	0.403	0.453	0.428	0.495	0.432	0.464
Mean	1.918	2.173		2.233	2.464		0.400	0.460		0.601	0.495	
L.S.D at 0.05 for	A= 0.0005 B=0.0010 AXB=0.0014			A= 0.017 B= 0.037 AXB=0.052			A= 0.0005 B=0.0010 AXB= 0.0014			A= 0.0005 B=0.0010 AXB=0.0014		

F_1: control, F_2: PGRB, F_3: NPK, F_4: Fe at 150 ppm, F_5: Fe at 100 ppm, F_6: Zn at 100 ppm, F_7: Zn at 75 ppm, F_8: Mn at 100 ppm, F_9: Mn at 75 ppm.

Table 6. Effects of planting distances, fertilization treatments and their interaction on potassium and total carbohydrates percentage/plant of *Thymus vulgaris* L. plants during 2017and 2018 seasons.

Parameters	**K (%)**						**Total carbohydrates (%)**					
Cutting	**1st cut**			**2nd cut**			**1st cut**			**2nd cut**		
Plant distance(A)	**Plant distance (A)**			**Plant distance (A)**			**Plant distance (A)**			**Plant distance (A)**		
Fertilization Treatments(B)	**20*20**	**30*30**	**Mean**	**20*20**	**30*30**	**Mean**	**20*20**	**30*30**	**Mean**	**20*20**	**30*30**	**Mean**
						1st season						
F_1	0.308	0.328	0.318	0.299	0.307	0.303	12.757	15.087	13.922	14.287	16.347	15.317
F_2	0.417	0.470	0.444	0.356	0.386	0.371	20.863	24.233	22.548	24.243	26.947	25.595
F_3	0.404	0.404	0.404	0.375	0.384	0.379	18.063	22.180	20.122	23.830	24.657	24.243
F_4	0.340	0.361	0.351	0.306	0.345	0.325	17.137	19.747	18.442	21.087	21.250	21.168
F_5	0.375	0.390	0.383	0.347	0.376	0.361	16.970	19.690	18.330	19.830	20.447	20.138
F_6	0.318	0.355	0.336	0.304	0.331	0.318	15.880	19.437	17.658	19.150	20.290	19.720
F_7	0.311	0.335	0.323	0.300	0.324	0.312	15.087	18.347	16.717	18.247	19.627	18.937
F_8	0.373	0.384	0.378	0.314	0.367	0.341	17.987	21.887	19.937	22.230	22.850	22.540
F_9	0.368	0.367	0.367	0.308	0.352	0.330	17.827	20.877	19.352	21.337	21.600	21.468
Mean	0.357	0.377		0.323	0.352		16.952	20.165		20.471	21.557	
L.S.D at 0.05 for	A= 0.0004 B=0.0008 AXB=0.0012			A=0.0005 B=0.0010 AXB=0.0013			A= 0.017 B= 0.037 AXB=0.052			A= 0.017 B= 0.037 AXB= 0.052		
						2nd season						
F_1	0.328	0.335	0.332	0.356	0.379	0.368	12.310	13.187	12.748	16.903	17.923	17.413
F_2	0.435	0.477	0.456	0.431	0.414	0.422	23.247	25.620	24.433	22.677	28.070	25.373
F_3	0.425	0.411	0.418	0.417	0.405	0.411	23.083	23.857	23.470	19.587	25.803	22.695
F_4	0.362	0.368	0.365	0.388	0.385	0.387	21.147	21.213	21.180	18.963	22.473	20.718
F_5	0.397	0.397	0.397	0.402	0.402	0.402	20.440	20.663	20.552	18.357	21.870	20.113
F_6	0.338	0.362	0.350	0.385	0.385	0.385	20.063	20.303	20.183	17.910	20.223	19.067
F_7	0.334	0.342	0.338	0.375	0.379	0.377	19.647	19.947	19.797	17.023	20.183	18.603
F_8	0.394	0.391	0.392	0.397	0.391	0.394	23.043	23.247	23.145	19.607	24.773	22.190
F_9	0.388	0.374	0.381	0.391	0.339	0.365	21.623	22.330	21.977	19.023	22.520	20.772
Mean	0.378	0.384		0.394	0.387		20.511	21.152		18.894	22.649	
L.S.D at 0.05 for	A= 0.0004 B=0.0008 AXB=0.0012			A= 0.0005 B=0.0010 AXB=0.0013			A= 0.099 B= 0.210 AXB=0.297			A= 0.017 B= 0.037 AXB= 0.052		

F_1: control, F_2: PGRB, F_3: NPK, F_4: Fe at 150 ppm, F_5: Fe at 100 ppm, F_6: Zn at 100 ppm, F_7: Zn at 75 ppm, F_8: Mn at 100 ppm, F_9: Mn at 75 ppm.

Chlorophyll A, B and Carotenoid's contents

Results in Tables (7 & 8) declared that chlorophyll (A, B), and carotenoid's contents, of thyme plant were increased by using planting distances of 30*30 cm in the two seasons. The greatest values of chlorophyll A, chlorophyll B and carotenoid's content were recorded by F2 (PGRB) treatment, followed by F3 (NPK). The highest values were obtained by using the combination treatment of planting distances (30*30 cm) and F2, followed descending by the combined treatment between planting distances (20*20cm) and F2 in two cuts and seasons. The abovementioned data are met with those attained by Tejeda-Sartorius *et al.* (2018), since the BFERT treatments led to increase the concentration of chlorophylls a, b. and (EL-Zawawy *et al.* 2021) on *Calendula officinalis* L., stated that using biofertilization led to increase in chlorophyll (A&B), and carotenoids.

Table 7. Effects of planting distances, fertilization treatments and their interaction on chlorophyll (A) and chlorophyll (B) content (mg/g F.W.) of *Thymus vulgaris* L. plants within 2017and 2018 seasons.

Parameters	**Chlorophyll A (mg/g fresh weight)**						**Chlorophyll B (mg/g fresh weight)**					
Cutting	**1st cut**			**2nd cut**			**1st cut**			**2nd cut**		
Plant distance(A)	**Plant distance (A)**			**Plant distance (A)**			**Plant distance (A)**			**Plant distance (A)**		
Fertilization Treatments(B)	**20*20**	**30*30**	**Mean**	**20*20**	**30*30**	**Mean**	**20*20**	**30*30**	**Mean**	**20*20**	**30*30**	**Mean**
						1st season						
F_1	0.552	0.573	0.563	0.671	0.692	0.682	0.247	0.268	0.258	0.274	0.295	0.284
F_2	1.127	1.148	1.138	1.141	1.162	1.151	0.502	0.523	0.513	0.507	0.528	0.518
F_3	1.037	1.058	1.048	1.097	1.118	1.108	0.462	0.483	0.472	0.469	0.490	0.479
F_4	0.834	0.855	0.845	0.984	1.005	0.995	0.385	0.406	0.395	0.387	0.408	0.398
F_5	0.719	0.740	0.730	0.877	0.898	0.887	0.348	0.369	0.358	0.362	0.383	0.373
F_6	0.650	0.671	0.660	0.832	0.853	0.843	0.313	0.334	0.324	0.325	0.346	0.335
F_7	0.576	0.597	0.587	0.812	0.833	0.823	0.305	0.326	0.316	0.310	0.331	0.320
F_8	0.951	0.972	0.962	1.052	1.073	1.063	0.434	0.455	0.445	0.408	0.429	0.419
F_9	0.879	0.900	0.890	1.005	1.026	1.016	0.403	0.424	0.413	0.411	0.432	0.422
Mean	0.814	0.835		0.941	0.962		0.378	0.399		0.384	0.405	
L.S.D at 0.05 for	A= 0.0012 B=0.0026 AXB=0.0037			A= 0.0011 B=0.0023 AXB=0.0033			A= 0.0012 B= 0.0026 AXB=0.0037			A= 0.0004 B=0.0008 AXB=0.0012		
						2nd season						
F_1	0.527	0.548	0.537	0.620	0.641	0.630	0.251	0.272	0.261	0.253	0.274	0.264
F_2	1.013	1.034	1.023	1.129	1.150	1.139	0.500	0.521	0.511	0.506	0.527	0.517
F_3	0.986	1.007	0.996	1.060	1.081	1.071	0.471	0.492	0.481	0.470	0.491	0.480
F_4	0.822	0.843	0.833	0.958	0.979	0.968	0.393	0.414	0.404	0.406	0.427	0.417
F_5	0.793	0.814	0.804	0.884	0.905	0.894	0.364	0.385	0.374	0.364	0.385	0.374
F_6	0.749	0.770	0.759	0.811	0.832	0.822	0.339	0.360	0.349	0.342	0.363	0.352
F_7	0.766	0.787	0.776	0.771	0.792	0.781	0.313	0.334	0.323	0.316	0.337	0.327
F_8	0.967	0.988	0.977	1.017	1.038	1.027	0.441	0.462	0.452	0.445	0.466	0.456
F_9	0.926	0.947	0.937	1.002	1.023	1.013	0.424	0.445	0.434	0.428	0.449	0.438
Mean	0.839	0.860		0.917	0.938		0.388	0.409		0.392	0.413	
L.S.D at 0.05 for	A= 0.017 B=0.037 AXB=0.052			A= 0.0011 B=0.0023 AXB=0.0033			A= 0.0005 B=0.0010 AXB=0.0014			A= 0.0004 B=0.0008 AXB=0.0012		

F_1: control, F_2: PGRB, F_3: NPK, F_4: Fe at 150 ppm, F_5: Fe at 100 ppm, F_6: Zn at 100 ppm, F_7: Zn at 75 ppm, F_8: Mn at 100 ppm, F_9: Mn at 75 ppm.

Zinc, Iron and Manganese percentage

Tables (9&10) reveal that Zn, Fe and Mn % /plant of thyme (*Thymus vulgaris* L.) plant were increased recorded by using planting distances (30*30 cm) in the two cuts at both seasons. The greatest values of iron (%) recorded by F4 (Fe at 150 ppm) treatment, followed by F5 (Fe at 100 ppm). The highest values was recorded by using the combination treatment of planting distances (30*30cm) and F4 followed by (30*30cm) and F5 in the second cut in two seasons. While the greatest values of Zinc (%) recorded by F2 (PGRB), followed by F8 (Mn at 100 ppm), the highest values was obtained by using the combination treatment of planting distances (30*30cm) and F4, followed descending by the combination treatment of planting distances (30*30 cm) and F5 in first cut in first season but in the second cut the highest values was (30*30) and F2 followed by (20*20) and F2. Furthermore, the highest values of manganese (%) obtained from F5 (Fe at 100 ppm) treatment, followed by F4 (Fe at 150 ppm) in two cuts in first season. While, the greatest values were given by F2 (PGRB), followed by F3 (NPK) in two cuts in the second season. Similar trend was obtained by (Rahimi *et al.* 2020) on *Ocimum basilicum* L. since they used organic and biofertilizers and obtained the greatest parameters. Furthermore, and (Nurzyńska-Wierdak *et al.* 2023) on *Melissa officinalis*, illustrated that planting distance (40 x 40cm) a better than (30 x 30cm) in improving the studied characteristics.

Table 8. Effects of planting distances, fertilization treatments and their interaction on carotenoid's content (mg/g F.W.), of *Thymus vulgaris* L. plants within 2017and 2018 seasons.

Parameters	**Carotenoids (mg/g fresh weight)**					
Cutting	**1st cut**			**2nd cut**		
Plant distance(A)	**Plant distance (A)**			**Plant distance (A)**		
Fertilization Treatments(B)	**20*20**	**30*30**	**Mean**	**20*20**	**30*30**	**Mean**
	1st season					
F_1	0.162	0.183	0.172	0.164	0.185	0.175
F_2	0.295	0.316	0.306	0.298	0.319	0.308
F_3	0.283	0.304	0.294	0.284	0.305	0.295
F_4	0.260	0.281	0.270	0.263	0.284	0.274
F_5	0.256	0.277	0.266	0.258	0.279	0.268
F_6	0.247	0.268	0.258	0.249	0.270	0.259
F_7	0.228	0.249	0.238	0.230	0.251	0.241
F_8	0.272	0.293	0.282	0.273	0.294	0.284
F_9	0.267	0.288	0.278	0.269	0.290	0.280
Mean	0.252	0.273		0.254	0.275	
L.S.D at 0.05 for	A= 0.0005 B=0.0010 AXB=0.0014			A= 0.0004 B=0.0008 AXB=0.0012		
	2nd season					
F_1	0.164	0.185	0.175	0.165	0.177	0.171
F_2	0.298	0.319	0.309	0.302	0.314	0.308
F_3	0.284	0.305	0.294	0.285	0.297	0.291
F_4	0.266	0.287	0.277	0.268	0.280	0.274
F_5	0.257	0.278	0.268	0.260	0.272	0.266
F_6	0.252	0.273	0.262	0.254	0.266	0.260
F_7	0.248	0.269	0.258	0.251	0.263	0.257
F_8	0.273	0.294	0.284	0.276	0.288	0.282
F_9	0.270	0.291	0.280	0.272	0.284	0.278
Mean	0.257	0.278		0.259	0.271	
L.S.D at 0.05 for	A= 0.0005 B=0.0010 AXB=0.0014			A= 0.0004 B=0.0008 AXB=0.0012		

F_1: control, F_2: PGRB, F_3: NPK, F_4: Fe at 150 ppm, F_5: Fe at 100 ppm, F_6: Zn at 100 ppm, F_7: Zn at 75 ppm, F_8: Mn at 100 ppm, F_9: Mn at 75 ppm.

Table 9. Effects of planting distances, fertilization and their interaction treatments on zinc and iron percentage /plant of *Thymus vulgaris* L. plants during 2017and 2018 seasons.

Parameters	**Zn (%)**						**Fe (%)**					
Cutting	**1st cut**			**2nd cut**			**1st cut**			**2nd cut**		
Plant distance(A)	**Plant distance (A)**			**Plant distance (A)**			**Plant distance (A)**			**Plant distance (A)**		
Fertilization Treatments(B)	**20*20**	**30*30**	**Mean**	**20*20**	**30*30**	**Mean**	**20*20**	**30*30**	**Mean**	**20*20**	**30*30**	**Mean**
	1st season											
F_1	0.020	0.033	0.026	0.010	0.016	0.013	0.024	0.033	0.028	0.029	0.035	0.032
F_2	0.028	0.044	0.036	0.029	0.030	0.030	0.036	0.044	0.040	0.039	0.039	0.039
F_3	0.022	0.055	0.038	0.018	0.020	0.019	0.041	0.055	0.048	0.040	0.041	0.041
F_4	0.018	0.076	0.047	0.016	0.019	0.017	0.079	0.076	0.077	0.069	0.078	0.073
F_5	0.019	0.075	0.047	0.013	0.017	0.015	0.077	0.075	0.076	0.063	0.072	0.067
F_6	0.017	0.056	0.037	0.008	0.012	0.010	0.046	0.056	0.051	0.611	0.053	0.332
F_7	0.017	0.063	0.040	0.004	0.011	0.007	0.052	0.063	0.058	0.653	0.058	0.355
F_8	0.027	0.066	0.047	0.025	0.027	0.026	0.072	0.066	0.069	0.060	0.067	0.064
F_9	0.023	0.061	0.042	0.021	0.023	0.022	0.065	0.061	0.063	0.051	0.063	0.057
Mean	0.021	0.059		0.016	0.019		0.055	0.059		0.179	0.056	
L.S.D at 0.05 for	A= 0.0004 B=0.0009 AXB=0.00012			A= 0.0005 B= 0.0010 AXB=0.0014			A= 0.0012 B=0.0026 AXB=0.0037			A= 0.0014 B=0.0024 AXB=0.0035		
	2nd season											
F_1	0.017	0.018	0.018	0.018	0.018	0.018	0.034	0.035	0.035	0.026	0.026	0.026
F_2	0.029	0.024	0.026	0.029	0.025	0.027	0.047	0.048	0.047	0.048	0.048	0.048
F_3	0.022	0.022	0.022	0.023	0.024	0.023	0.052	0.052	0.052	0.052	0.053	0.053
F_4	0.019	0.021	0.020	0.020	0.021	0.020	0.079	0.079	0.079	0.080	0.081	0.080
F_5	0.020	0.021	0.021	0.021	0.022	0.021	0.076	0.076	0.076	0.077	0.077	0.077
F_6	0.018	0.021	0.019	0.019	0.021	0.020	0.068	0.070	0.069	0.071	0.072	0.071
F_7	0.017	0.019	0.018	0.017	0.019	0.018	0.072	0.072	0.072	0.073	0.073	0.073
F_8	0.028	0.024	0.026	0.028	0.024	0.026	0.079	0.079	0.079	0.079	0.080	0.080
F_9	0.024	0.023	0.023	0.024	0.023	0.024	0.066	0.069	0.0680.	0.069	0.069	0.069
Mean	0.022	0.021		0.022	0.022		0.064	0.064		0.064	0.064	
L.S.D at 0.05 for	A= 0.0005 B=0.0010 AXB=0.0014			A= 0.0016 B=0.0033 AXB=0.0047			A= 0.0016 B=0.0033 AXB=0.0047			A= 0.0004 B=0.0008 AXB=0.0012		

F_1: control, F_2: PGRB, F_3: NPK, F_4: Fe at 150 ppm, F_5: Fe at 100 ppm, F_6: Zn at 100 ppm, F_7: Zn at 75 ppm, F_8: Mn at 100 ppm, F_9: Mn at 75 ppm.

Table 10. Effects of planting distances, fertilization treatments and their interaction on manganese% /plant of *Thymus vulgaris* L. plants during 2017and 2018 seasons.

Parameters	Mn (%)					
Cutting	1st cut			2nd cut		
Plant distance(A)	Plant distance (A)			Plant distance (A)		
Fertilization Treatments(B)	20*20	30*30	Mean	20*20	30*30	Mean
	1st season					
F_1	0.021	0.021	0.021	0.021	0.021	0.021
F_2	0.017	0.018	0.018	0.018	0.018	0.018
F_3	0.016	0.017	0.017	0.017	0.017	0.017
F_4	0.022	0.022	0.022	0.022	0.022	0.022
F_5	0.024	0.024	0.024	0.024	0.024	0.024
F_6	0.018	0.018	0.018	0.018	0.018	0.018
F_7	0.015	0.015	0.015	0.015	0.061	0.038
F_8	0.015	0.015	0.015	0.015	0.016	0.015
F_9	0.016	0.017	0.017	0.017	0.017	0.017
Mean	0.018	0.018		0.018	0.024	
L.S.D at 0.05 for	A= 0.0004 B=0.0008 AXB=0.0012			A= 0.0012 B=0.0026 AXB=0.0037		
	2nd season					
F_1	0.018	0.018	0.018	0.018	0.339	0.179
F_2	0.020	0.020	0.020	0.020	0.353	0.186
F_3	0.019	0.019	0.019	0.019	0.305	0.162
F_4	0.012	0.012	0.012	0.013	0.276	0.145
F_5	0.014	0.015	0.015	0.015	0.281	0.148
F_6	0.011	0.012	0.011	0.011	0.249	0.130
F_7	0.010	0.010	0.010	0.010	0.234	0.122
F_8	0.018	0.018	0.018	0.018	0.301	0.159
F_9	0.017	0.017	0.017	0.017	0.296	0.156
Mean	0.015	0.016		0.016	0.293	
L.S.D at 0.05 for	A= 0.0011 B=0.0023 AXB=0.0033			A= 0.0011 B=0.0023 AXB=0.0033		

F_1: control, F_2: PGRB, F_3: NPK, F_4: Fe at 150 ppm, F_5: Fe at 100 ppm, F_6: Zn at 100 ppm, F_7: Zn at 75 ppm, F_8: Mn at 100 ppm, F_9: Mn at 75 ppm.

Effect of planting distances and fertilization treatments and their interaction treatments on essential oils yield and composition of *Thymus vulgaris,* L. plants during 2017 & 2018 seasons.

Tables (11) reveals that, the essential oils percentage / plant of thyme plant was increased by using planting distances (30*30 cm) in two cuts and in both seasons. The results showed that essential oils per plant was greatly affected by all fertilizer's treatments in two seasons. Hence, the results in these characters were statistically induced by F2 (PGRB), followed by F3 (NPK).Data shown in the same Table revealed that combination between planting distances and fertilizations treatments increased the parameter mentioned before of thyme plant. the highest values was obtained by using the combination between planting distance (30*30cm) and F2, followed descending by the combination treatment of planting distances (20*20cm) and F2 in both seasons. Also, the abovementioned results are met with those attained by Rahimi *et al.* (2020) using organic and biofertilizer since the biggest impact on essential oil content was caused. Moradzadeh *et al* (2021) on *Nigella sativa* L. found that NPK (b) + U50% produced the highest essential oil content. In addition, (Nguyen *et al.* 2022) on *Ocimum tenuiflorum* L. revealed that the greatest essential oils content was obtained from at spacing of 40 x 50 cm. Furthermore, Mirjalili *et al*. (2022) on *Satureja bachtiarica Bunge*, and Mohamed *et al.* (2023) on *Artemisia annua* L., obtained the greatest values of essential oils % from planting distance of 40*40 cm.

Essential oil constituents

Tables (12 and13) and Figures, (1-18) results cleared the effects of fertilizers and plant distances at (30*30 cm) and (20*20 cm) on the components of essential oilsof thyme plant, The volatile oil compounds of thyme is 12 compounds were such as α-thujene, α-pinene, camphene, sabinene, p-cymene, linalool, γ-terpinene, terpinenolene, borneol, bornyl acetate, thymol, carvacrol. In two cuts and in both seasons, the main component was β-cymene ranged from (28.625 to 39.73 %), followed by thymol ranged from (14.83 to 24.95 %), borneol ranged from (2.95 to 16.01 %), terpinenolene ranged from (4.67 to 9.25), α-thujene ranged from (4.05 to 7.17), bornyl acetate ranged from (2.37 to 6.72), carvacrol ranged from (3.23 to 6.59), sabinene ranged from (2.02 to 6.55), camphene ranged from (2.64 to 4.56), α-pinene ranged from (1.01 to 3.86), γ-terpinene ranged from (1.46 to 2.86) and linalool ranged from (1.19 to 2.53). In addition, Nadjafi *et al.* (2014) on *thymus vulgaris* L., and *Salvia officinalis* L., and Punetha *et al.* (2022) and Yasuj *et al.* (2023) on (*thymus vulgaris,* L.), found that the quantity of β-cymene increased considerably, by a considerable decline was in temperature conditions were detected during storage

Table 11. Effects of planting distances, fertilization treatments and their interaction on essential oil % in fresh herb/plant of *Thymus vulgaris* L. plants during 2017& 2018 seasons.

Parameters	Oil Percentage (%)					
Cutting	1st cut			2nd cut		
Plant distance(A)	Plant distance (A)			Plant distance (A)		
Fertilization Treatments(B)	20*20	30*30	Mean	20*20	30*30	Mean
	1st season					
F_1	0.193	0.210	0.202	0.227	0.250	0.238
F_2	0.737	0.763	0.750	0.767	0.797	0.782
F_3	0.673	0.703	0.688	0.700	0.730	0.715
F_4	0.427	0.457	0.442	0.453	0.490	0.472
F_5	0.390	0.417	0.403	0.430	0.460	0.445
F_6	0.267	0.300	0.283	0.297	0.320	0.308
F_7	0.330	0.347	0.338	0.360	0.383	0.372
F_8	0.470	0.490	0.480	0.497	0.523	0.510
F_9	0.507	0.533	0.520	0.540	0.563	0.552
Mean	0.444	0.469		0.474	0.502	
L.S.D at 0.05 for	A= 0.0004 B=0.0008 AXB=0.0012			A= 0.0005 B=0.0010 AXB=0.0014		
	2nd season					
F_1	0.203	0.213	0.208	0.227	0.250	0.238
F_2	0.757	0.787	0.772	0.783	0.810	0.797
F_3	0.690	0.723	0.707	0.723	0.743	0.733
F_4	0.457	0.497	0.477	0.473	0.497	0.485
F_5	0.417	0.437	0.427	0.437	0.463	0.450
F_6	0.303	0.330	0.317	0.330	0.347	0.338
F_7	0.353	0.383	0.368	0.370	0.407	0.388
F_8	0.493	0.527	0.510	0.517	0.557	0.537
F_9	0.533	0.560	0.547	0.553	0.590	0.572
Mean	0.467	0.495		0.490	0.518	
L.S.D at 0.05 for	A= 0.0004 B=0.0009 AXB=0.0013			A= 0.0005 B= 0.0010 AXB=0.0014		

F_1: control, F_2: PGRB, F_3: NPK, F_4: Fe at 150 ppm, F_5: Fe at 100 ppm, F_6: Zn at100 ppm, F_7: Zn at 75 ppm, F_8: Mn at 100 ppm, F_9: Mn at 75 ppm.

Table 12. GLC analysis of the essential oil of *Thymus vulgaris,* L. plants at planting distances (30*30), fertilizations treatments and their interaction in Second cut of the second season.

Tre. No. Components	F1	F2	F3	F4	F5	F6	F7	F8	F9
α-Thujene	5.826	7.171	4.059	4.597	5.046	4.911	5.922	4.930	4.560
α- pinene	3.869	1.961	1.348	1.982	2.112	2.135	1.044	1.394	2.019
Camphene	2.942	4.561	3.308	3.570	3.323	3.257	3.664	3.284	3.073
Sabinene	2.529	6.555	2.455	5.922	2.008	2.029	5.250	2.343	2.051
β- Cymene	28.625	36.597	39.739	39.349	36.854	36.270	37.891	36.615	34.680
Linalool	1.938	2.527	2.530	1.851	2.066	2.011	1.462	1.501	2.086
γ-Terpinene	1.580	2.866	1.571	1.624	2.020	1.971	2.067	2.080	2.153
Terpinenolene	6.192	9.259	6.161	5.691	5.736	5.864	5.254	5.905	5.594
Borneol	16.016	3.010	3.034	4.201	12.010	12.296	3.990	7.720	5.118
Bornyl acetate	6.727	7.120	2.645	6.154	4.768	6.586	2.376	2.808	4.645
Thymol	16.279	24.959	22.276	19.822	19.669	18.487	19.214	21.035	21.174
Carvacrol	2.708	6.595	5.171	3.743	3.603	4.176	4.214	5.285	5.269
Total									

F_1: control, F_2: PGRB, F_3: NPK, F_4: Fe at 150 ppm, F_5: Fe at 100 ppm, F_6: Zn at 100 ppm, F_7: Zn at 75 ppm, F_8: Mn at 100 ppm, F_9: Mn at 75 ppm.

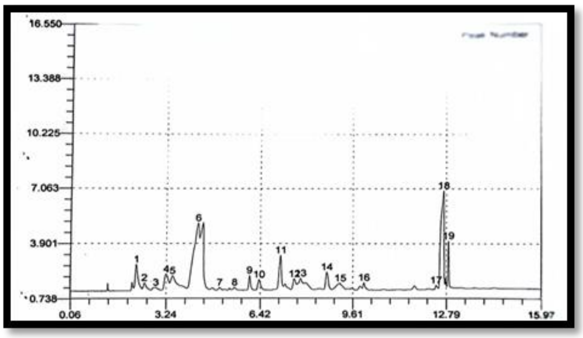

Fig. 1. Chromatogram of thyme (*Thymus vulgaris,* L.) essential oils distilled from F2 (PGRB) on planting distance 30*30cm in the 2nd cut and 2nd

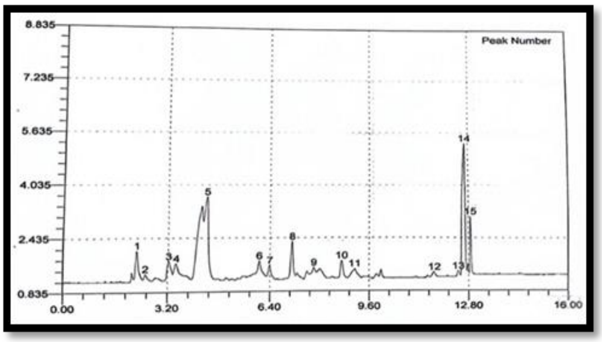

Fig. 2. Chromatogram of thyme (*Thymus vulgaris,* L.) essential oils distilled from F3 (NPK) on planting distance 30*30cm in the 2nd cut and 2nd

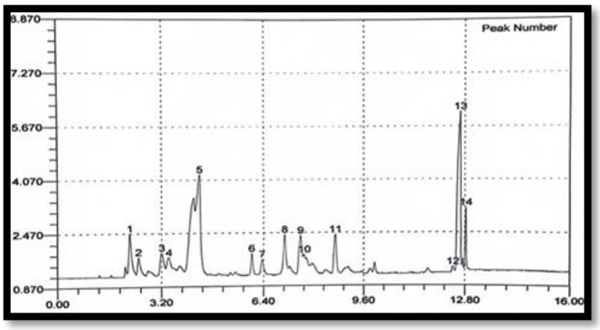

Fig. 3. Chromatogram of (*Thymus vulgaris,* L.) essential oils distilled from F9 (Mn75) on planting distance 30*30cm in the 2nd cut and 2nd

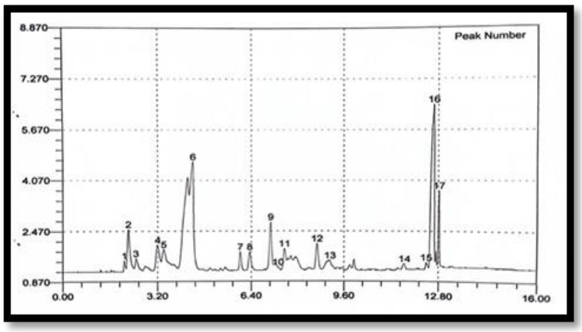

Fig. 4. Chromatogram of (*Thymus vulgaris,* L.) essential oils distilled from F8 (Mn100) on planting distance 30*30cm in the 2nd cut and 2nd

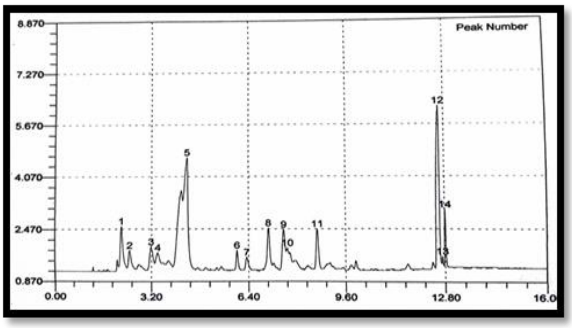

Fig. 5. Chromatogram of (*Thymus vulgaris,* L.) essential oils distilled from F4 (Fe150) on planting distance 30*30cm in the 2nd cut and 2nd

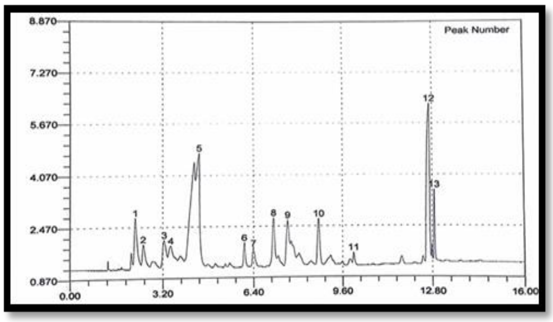

Fig. 6. Chromatogram of (*Thymus vulgaris,* L.) essential oils distilled from F5 (Fe100)on planting distance 30*30cm in the 2nd cut and 2nd

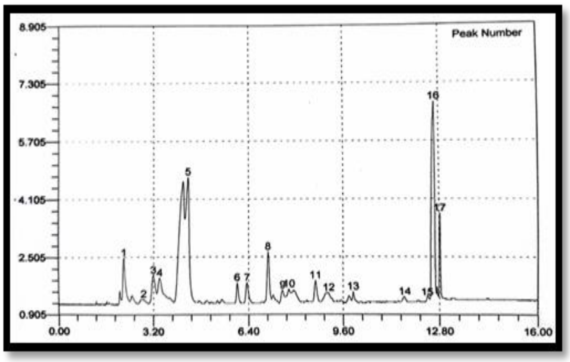

Fig. 7. Chromatogramof (*Thymus vulgaris*, L.) essential oils distilled from F7 (Zn75) on planting distance 30*30cm in the 2nd cut and 2nd

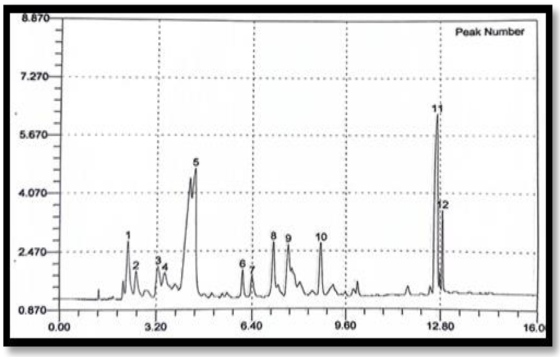

Fig. 8. Chromatogramof (*Thymus vulgaris*, L.) essential oils distilled from F6 (Zn100) on planting distance 30*30cm in the 2nd cut and 2nd

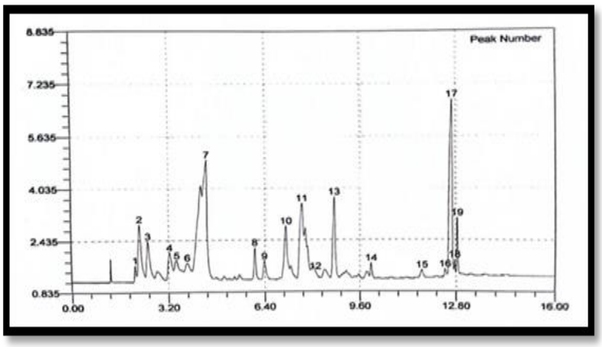

Fig. 9. Chromatogram of (*Thymus vulgaris*, L.) essential oils distilled from F1 (cont.) on planting distance 30*30cm in the 2nd cut and 2nd

Table 13. GLC analysis of the essential oil of *Thymus vulgaris*, L. plants at planting distances (20*20), fertilizations treatments and their interaction in second cut of the second season.

Tre. No. Components	F1	F2	F3	F4	F5	F6	F7	F8	F9
α-Thujene	5.218	4.789	5.199	5.015	5.333	5.255	5.593	5.934	6.107
α- pinene	2.609	1.138	2.122	2.348	2.263	2.234	2.428	2.879	1.015
Camphene	3.062	3.301	3.618	3.288	3.041	3.000	3.666	3.294	3.730
Sabinene	5.558	2.424	2.255	2.048	5.774	5.690	6.051	2.121	5.266
β- Cymene	35.671	39.454	36.764	36.613	34.175	32.809	34.931	34.697	37.705
Linalool	1.195	2.462	2.047	2.030	1.472	1.464	1.841	1.921	1.366
γ-Terpinene	1.468	1.529	2.025	1.990	1.682	1.684	1.805	2.029	1.923
Terpinenolene	4.919	6.431	4.673	5.919	5.424	5.366	5.367	4.885	5.149
Borneol	7.763	2.953	4.214	11.426	7.006	6.910	10.362	9.856	3.991
Bornyl acetate	3.759	2.575	6.124	4.685	4.382	4.327	4.249	3.976	2.398
Thymol	14.837	21.681	20.216	19.136	17.576	17.284	17.288	19.136	20.031
Carvacrol	3.237	5.171	3.831	4.968	4.465	4.486	4.424	3.794	4.773
Total									

F_1: control, F_2: PGRB, F_3: NPK, F_4: Fe at 150 ppm, F_5: Fe at 100 ppm, F_6: Zn at 100 ppm, F_7: Zn at 75 ppm, F_8: Mn at 100 ppm, F_9: Mn at 75 ppm.

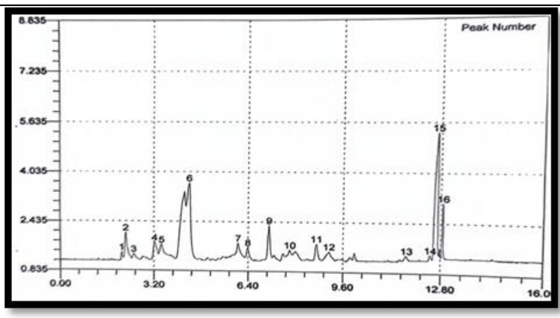

Fig. 10. Chromatogram of (*Thymus vulgaris*, L.) essential oils distilled from F2 (PGRB) on planting distance 20*20cm in the 2nd cut and 2nd

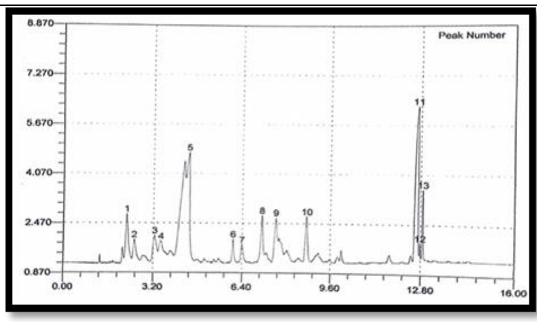

Fig. 11. Chromatogram of (*Thymus vulgaris*, L.) essential oils distilled from F3 (NPK) on planting distance 20*20cm in the 2nd cut and 2nd

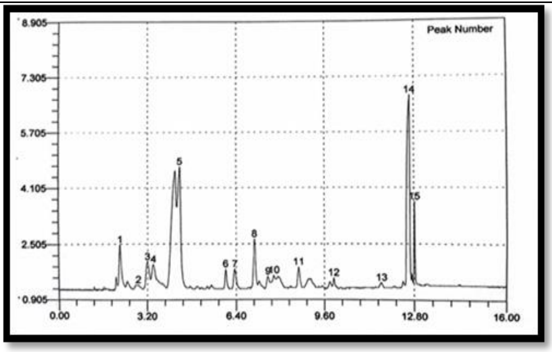

Fig. 12. Chromatogram of (*Thymus vulgaris*, L.) essential oils distilled from F9 (Mn75) on planting distance 20*20cm in the 2nd cut and 2nd

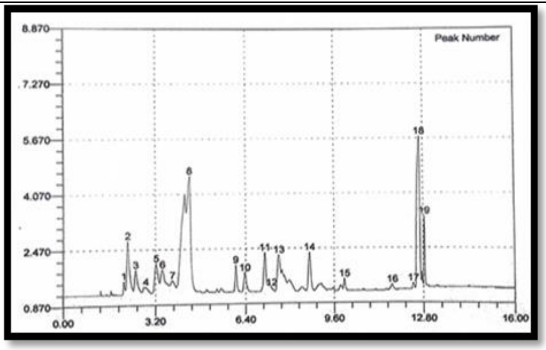

Fig. 13. Chromatogram of (*Thymus vulgaris*, L.) essential oils distilled from F8 (Mn100)on planting distance 20*20cm in the 2nd cut and 2nd

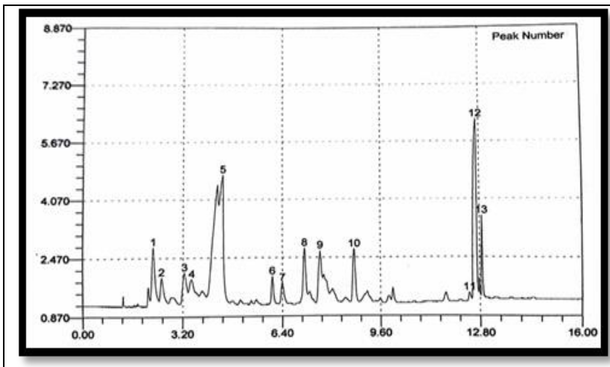

Fig. 14. Chromatogram of (*Thymus vulgaris*, L.) essential oils distilled from F4 (Fe150) on planting distance 20*20cm in the 2nd cut and 2nd

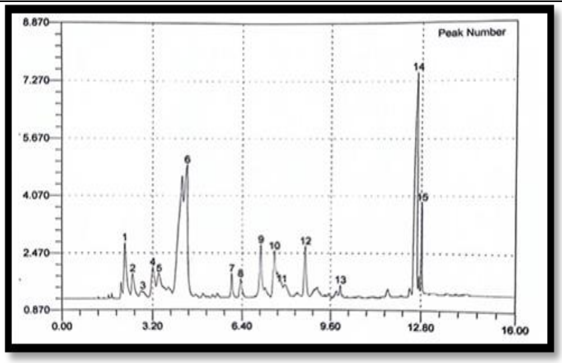

Fig. 15. Chromatogram of (*Thymus vulgaris*, L.) essential oils distilled from F5 (Fe100)on planting distance 20*20cm in the 2nd cut and 2nd

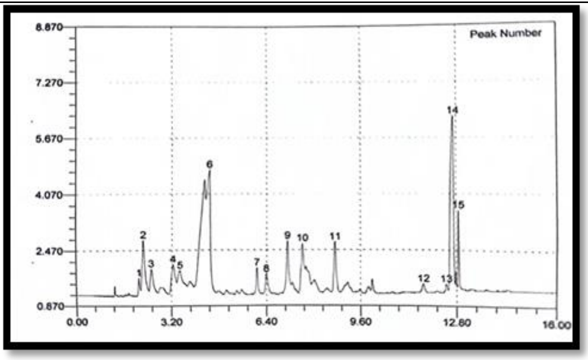

Fig. 16. Chromatogram of (*Thymus vulgaris*, L.) essential oils distilled from F7 (Zn75) on planting distance 20*20cm in the 2nd cut and 2nd

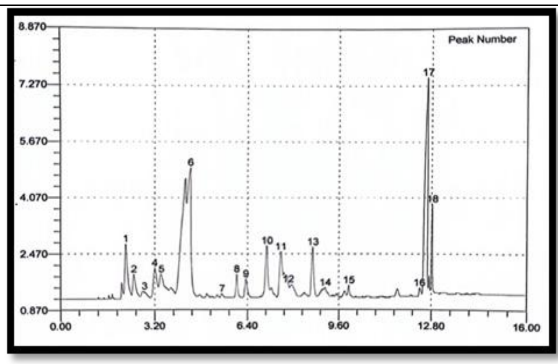

Fig. 17. Chromatogram of (*Thymus vulgaris*, L.) essential oils distilled from F6 (Zn100) on planting distance 20*20cm in the 2nd cut and 2nd

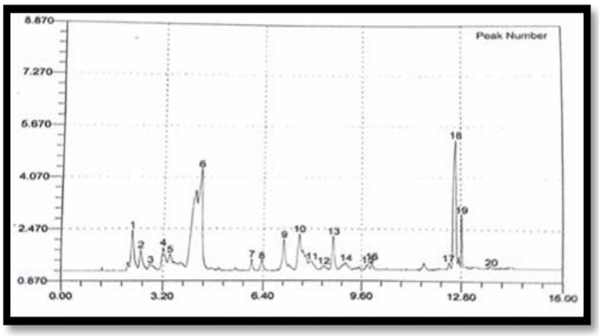

Fig. 18. Chromatogram of (*Thymus vulgaris*, L.) essential oils distilled from F1 (cont.) on planting distance 20*20cm in the 2nd cut and 2nd

Conclusively, its better to apply the planting distances of 30*30 cm and F_2 (PGRB), followed byF_3 (NPK)for enhancing all studied traits of thyme plant.

REFERENCES

A.O.A.C. (1990). Official Methods of Analysis (15th Ed.). Association of Official Analytical Chemists, Washington, DC, USA.

Ahmed, N. W. and Zahwan, T. A. (2022). The role of spraying with NPK chemical fertilizer and organic fertilizer on some vegetative and floral indicators and the Active ingredients *Origanum majorana*. Tikrit Journal for Agricultural Sciences 22(4):143-151.

Aslin, L. O.; Supryiono , E .; Nirmala , K.; Nurjanah, D. and Soelistyowati, T. (2019). The effects of planting distances and seedling sources on Kappaphycus alvarezii growth. : Earth and Environmental Science 278.

Bargaz, A.; Lyamlouli, K.; Chtouki, M.; Zeroual, Y.and Dhiba, D. (2018). Soil microbial resources for improving fertilizers efficiency in an integrated plant nutrient management system. Front. Microbiol.Vol. 9 Article: 1606.

Black, C.A.;Evans,D.O.; Ensminger, L.E.;White, J.L.; Clark, F.E. and Dinauer,R.C. (1982).Methods of Soil Analysis. part 2. Chemical and microbiological properties. 2nd Ed. Soil Sci., Soc. of Am. Inc. Publ., Madison, Wisconsin, U. S.A.

British Pharmacopeia, (1963). Determination of Volatile Oil in Drugs. The Pharmaceutical Press, Lond., W. C. L., 213 p.

Bunzen, J.; N. Guidchard; J. labbe; P. prevot; J. Sperpinet and Trenchant,J. (1969). Practical manual of gas Chromatography. J. Trenchant Ed., El-Seivier publ. Comp., Amesterdam, London.

Chapman, H.D. and Paratt, P.F. (1961). Methods of Soil, Plants and Water Analysis. Univ. California, Div. Agric. Sci., 314p.

EL-Zawawy, H. A. H.; Nada, R. S. and Saad, Z. H. (2021). The Effect of Organic and Bio-Fertilization on some Physical and Chemical Properties of Calendula officinalis L. Plant. J. of Agricultural Chemistry and Biotechnology, Mansoura Univ., Vol. 12 (3):69-73.

Fathi, S.; Bolandnazar, S.; Alizadeh-Salteh, S. and Zaare-Nahandi, F. (2022).Effects of Biological Fertilizers on Some Physiological Traits of Sweet Basil under Water Deficit Stress. Journal of Medicinal Plants and By-products Original Article.

Chandra, N. R.; Devendra, S. and Krishna, T. S. (2022).Influence of crop geometry and bio-fertilizer application on growth and yield of *phyllanthus amarus* Schumach. &Thonn. Medicinal Plants-International Journal of Phytomedicines and Related Industries. Volum 14(3) 507-512.

Hammoudi Halat, D.; Krayem, M.;Khaled, S.; and Younes, S.(2022).a Focused Insight into Thyme: Biological, Chemical, and Therapeutic Properties of an Indigenous Mediterranean Herb. Nutrients, 14(10): 2104.

Herbert, D.; Phipps, P.J. and Strange, R.E. (1971). Determination of total carbohydrates, Methods in Microbiology, 5 (8): 290-344.

Hoftman, E. (1967). Chromatography, Reinhold publ. corp., 2nd. Ed. pp. 208 – 515.

Horneck, D.A. and Hanson, D. (1998).Determination of potassium and sodium by flame Emission spectrophotometry. In hand book of reference methods for plant analysis, e.d Kolra, Y. P.(e.d). 153-155.

Horneck, D.A. and Miller, R.O. (1998). Determination of total nitrogen in plant hand book of reference methods for plant analysis, (e.d) Kolra,Y.P73.

Hucker, T. and Catroux G. (1980). Phosphorus in sewage ridge and animal's wastes slurries. Proceeding of the EEC Seminar, Haren (Gr): Gromingen Netherlands 12, 13 June.

Jackson, M.L., (1973). Soil Chemical Analysis. Prentice-Hall of Indian Private, New Delhi. Jedrzejczak R., W. Reczajska and B. Szteke, 1999. Magnez i inne makroelementy w rooelinnych surowcach jadalnych. [Magnesium and other macronutrients in edible plant raw materials]. Biul. Magnezol, 4(1): 72-76. (In Polish).

Mirjalili, A.; Lebaschi, M. H.; Ardakani, M. R.; Sharifabad, H. H. andMirza, M. (2022). Plant Density and Manure Application Affected Yield and Essential Oil Composition of Bakhtiari Savory (Satureja bachtiarica Bunge.), Industrial crops and products; V.177: PP.114516.

Mohamed, S.M., Abou El-Ghait, E.M. Ghatas, Y.A. El Shayieb, N.M. and Shahin, A.A.S. (2015). Effect of some fertilizers on improving growth and oil productivity of basil (*Ocimum basilicum*, L.) cv. Genovese plant. Egypt. J. of Appl. Sci., 30(6):384-399.

Mohamed, Y.F.Y. and Ghatas, Y.A.A. (2016). Effect of mineral, biofertilizer (EM) and zeolite on growth, flowering, yield and composition of volatile oil of Viola odorata L. plants. Journal of Horticultural Science & Ornamental Plants, 8(3):140-148.

Mohamed, S. M.; Mohamed, Y.F.Y.; Saleh, D. M. and Eman M. A. (2023). 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. J. of PlantProduction, Mansoura Univ., Vol. 14 (2):31 - 43.

Mokhtari, R.; Fard, M. K.; Rezaei, M.; Moftakharzadeh, S. D. and Mohseni, A. (2023). Antioxidant, Antimicrobial Activities, and Characterization of Phenolic Compounds of Thyme (*Thymus vulgaris* L.), Sage (*Salvia officinalis* L.), and Thyme-Sage Mixture Extracts. Journal of Food Quality. Volume 2023 (8):1-9.

Moradzadeh, M., Moghaddam, S. S., Rahimi, A., Pourakbar, L., Sayyed, R. Z. (2021). Combined bio-chemical fertilizers ameliorate agro-biochemical attributes of black cumin (*Nigella sativa* L.). Scientific Reports vol. 11, Article number: 11399 (2021).

Mounika, Y.; Sivaram, G. T.; Reddy, P. S. S. and Ramaiah, M. (2018). Influence of biofertilizers and micronutrients on growth, seed yield and quality of coriander (*Coriandrum sativum* L.) cv. Sadhana. Int. J. Curr. Microbiol. Appl. Sci., 7(1): 2099-2107.

Nadjafi, F., Mahdavi Damghani, M., Tabrizi, L. and Nejad Ebrahimi, S. (2014). Effect of biofertilizers on growth, yield and essential oil content of thyme (*Thymus vulgaris* L.) and sage (*Salvia officinalis* L.) J. of Essen. Oil Bear. Sci. and Manag. 232-237.

Nguyen, D. M. C.; Luong, T. H. and Jung, W. J. (2022). Effect of accession and spacing on the essential oil yield and yield components of holy basil (*Ocimum tenuiflorum*). Journal Research on Crops. Vlo. 23(1): 220-228.

Nurzyńska-Wierdak, R.; Zawiślak, G. and Papliński, R. (2023).Agronomic Practices in *Lemon Balm* Production under Temperate Climate Conditions: Raw Material Yield and Active Substances Content. Journal Agronomy, Vol. 13(5): 17-23.

Punetha, A.; Chauhan, A.; Kumar, D.; Venkatesha, K. T.; Upadhyay, R. K. and Padalia, R. C. (2022). Productivity and essential oil quality of Himalayan Thyme (*Thymus linearis* Benth.) in relation to plant densities and drying methods. Journal of Essential Oil Research, Vol.34 (3) 262-269.

Rahimi, A.; Özyazici, G. and Ahmadi, F. (2020). Effect of Biological, Organic and Chemical Fertilizers on Some Antioxidant Activities and Yield of Basil (*Ocimum basilicum* L.). Euroasia Journal of Mathematics, Engineering, Natural & Medical Sciences. International Indexed & Refereed, ISSN 2667-6702.

Sahu, D.; Priyadarshani, I. and Rath, B. (2012). Cyanobacteria - as potential biofertilizer. CibTech Journal of Microbiology ISSN: 2319-3867.

Shahverdi, M. A.; Dehaghi, M. A.; Somagh, H. A. and Mamivanad, M. (2019). The Effect of Different Nutritional Systems with Nitrogen and Phosphorous Fertilizers on Quantitative and Qualitative Traits of Basil (*Ocimum basilicum* L.). Journal of Plant Productions (Scientific Journal of Agriculture), 41(4) 1-14.

Singh, M., Singh, D., Gupta, A., Pandey, K. D., Singh, P. K., and Kumar, A. (2019). "Plant growth promoting rhizobacteria," in PGPR Amelioration in Sustainable Agriculture, eds A. K. Singh, A. Kumar, and P. K. Singh (Cambridge, MA: Elsevier), 41–66.

Snedecor, G.W. and Cochran,W.G.(1989).Statistical methods. 6 th Ed. The Iowa state Univ. Press, Ames., Iowa. U.S.A.

Tejeda-Sartorius, O.; Trejo-Téllez, L. I.; Ríos-Barreto, Y. and Rodríguez, J. L. (2018). Mineral fertilization and biofertilization in physiological parameters of the orchid Laelia anceps subsp. Rev. Chapingo Ser.Hortic vol.24. No.3.

Xing, J.; Jingwen, X. and Hongxiao, Z. (2023). Environmental effects of rural e-commerce: A case study of chemical fertilizer reduction in China. Journal of Environmental Management. Volume 326, Part A, 15, 116713.

Yasuj, S. F. M.; Najafian, S. and Hosseinifarahi, M. (2023). Investigating the Storage Conditions of the Essential Oil Compounds of Garden Thyme. Journal of Medicinal Plants and By-products.

Yousef, A. F.; Youssef, M. A.; Ali, M. M.; Ibrahim, M. M.; Xu, Y.; Mauro, R. P. (2020). Improved Growth and Yield Response of Jew's Mallow (*Corchorus olitorius* L.) Plants through Biofertilization under Semi-Arid Climate Conditions in Egypt. Agronomy, 10(11), 1801.

استجابة نبات الزعتر لمسافات الزراعة ومعاملات التسميد

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الملخص

ينتمى نبات الزعتر (*Thymus vulgaris* L) إلى العائلة الشفوية. ويعتبر الزعتر نباتًا مهمًا صالحًا للأكل تمت دراسته لعدة قرون لأهميته الفريدة في صناعة الأغذية والأدوية ومستحضرات التجميل. تم إجراء هذا البحث خلال موسمي الزراعة المتتاليين 2017 و 2018 في المزرعة التجريبية بقسم البساتين بكلية الزراعة- جامعة بنها لدراسة تأثير مسافات الزراعة المختلفة (20 * 20 سم و 30 * 30 سم) والأسمدة الحيوية (PGRB) والأسمدة الكيماوية (NPK) والمغذيات الصغرى (الزنك والحديد والمنجنيز) علي نبات الزعتر. أظهرت النتائج في كل من الحشتين في كلا الموسمين أن القيم القصوي للنمو الخضري قد سجلت باستخدام المعاملة المشتركة بين مسافات الزراعة (30 * 30 سم) والسماد الحيوي F2 (PGRB). وبالتالي فإن الجمع بين مسافات الزراعة ومعاملات التسميد يعزز التركيبات الكيميائية خاصة مسافة الزراعة (30 * 30 سم) و F2 في الحشتين وفي كلا الموسمين في معظم الحالات. تمت زيادة نسبة الزيت العطرى لنبات الزعتر باستخدام معاملة التفاعل بين لمسافات الزراعة (30 * 30 سم) و F2. اشتمل تحليل GLC للزعتر على 12 مركبًا ، المكون الرئيسي كان بيتا سيامين (β-Cymene). يوصى بتطبيق مسافة الزراعة (30 * 30 سم) و F2 لتعزيز جميع الصفات المدروسة لنبات الزعتر.