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The impact of NPK fertilization level and Lithovit concentration on productivity and active ingredients of *Coriandrum sativum* plants

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ABSTRACT

Two field experiments were carried out at Ghazala Experimental Farm, Fac.Agric., Zagazig Univ., Egypt, during the two consecutive seasons of 2016/2017 and 2017/2018 to investigate the effect of different NPK fertilization levels (0.0, 50, 75 and 100 % of recommended rate), Lithovit concentrations (0.0, 2 , 4 and 6 g / liter) and their combination treatments on growth, yield and its components, volatile oil and some chemical constituents of coriander plant.Plants were foliar sprayed with Lithovit three times at 30, 50 and 70 days after sowing. The statistical layout of this experiment was split- plot experiment included sixteen treatments were arranged in a randomized complete block design with three replicates. Obtained results demonstrated that the maximum values of plant height, No. of leaves/plant, root length, total dry weight/plant, fruit yield / plant and / fed. and total carbohydrates % were detected when plants were fertilize with $N_2P_2K_2$ or $N_3P_3K_3$ and sprayed with Lithovit at 6 g/l. While, the highest No. of branches/plant, No. of inflorescences/plant, volatile oil %, volatile oil yield/ plant and fed., N, P, K percentages and total chlorophyll content in leaf tissueswere recorded as coriander plants were fertilized with $N_3P_3K_3$ and sprayed with 6 g/l Lithovit. The main constituents of *Coriandrium sativum* fruits as detected by GC/MS were linalool and camphor which increased with treatment of $N_3P_3K_3$ and Lithovit at 6 g/l compared to control.

Key words: *Coriandrium sativum,* Lithovit, NPK, volatile oil, fruit yield.

Introduction

The coriander plant (*Coriandrum sativum* L.) belonging to family *Apiaceae* is an annual herbaceous plant which originated from the Mediterranean area but is extensively cultivated in North Africa, Central Europe and Asia as a culinary and is cultivated in Egypt. At one time, coriander was among the top 20 essential oil plants (Lawrence, 1993). Dried fruits are ground and widely used as flavoring agent in food products or as condiment or spice, while its tender green leaves are used as culinary herbs.

Application of N, P and K at 80, 60 and 30 kg/ha , respectively gave maximum plant height, leaf number, number of branches, fresh weight of plant and seed yield of coriander (Bhat *et al.*, 1992). Fertilizing coriander plants with N, P,K and S at 70,50,30 and 20 Kg / ha , respectively gave the highest plant height , number of primary branches /plant , number of umbel / plant and seed yield (Yousef *et al.*, 2014). Seed yield of coriander was higher when 100% fertilizer dose was used but yield decreased when 25% less fertilizer applied (Kamrozzaman *et al.*, 2016).

Lithovit fertilizer consists of calcium - magnesium carbonate $(Ca,Mg)CO_3$, supplemented by numerous important micronutrients. On the foliage, the Lithovit particles penetrate in part directly through the stomata of the leaves into the intercellular compartments. The rest remains on the leaves as a film. Although, Lithovit acts as an excellent fertilizer, the mechanism of its action is still not totally clear. Most likely, it is due to supplying the plants with Carbon dioxide (CO_2) in much higher concentration than that in the atmosphere and so enabling the photosynthesis to take place with higher degree leading to a stronger natural growth and, consequently, increased yield. Furthermore, the supplements of micro-nutrients increase the enzymatic activity that plays a role in this process. The release of CO_2 from the Lithovit remaining on the leaves surface is probably due to its transformation to $(Ca,Mg)(HCO_3)_2$ during the night by means of CO_2 (produced by the plants in addition to that in the

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atmosphere) and H_2O (which covers the leaves as dew in addition to that produced by the plants). During the day the temperature rises gradually, water evaporation occurs and the $(Ca,Mg)(HCO_3)_2$ is back transformed to Lithovit giving CO_2 on high concentration directly in the leaves surface. In that way Lithovit acts as quasi permanent catalytic depot (Bilal, 2010).

The interest in foliar fertilizers arose due to its multiple advantages such as rapid and efficient response to the plant, less product needed, and independence on soil conditions. It is also recognized that supplementary foliar fertilization during crop growth can improve the mineral status of plants and increase the crop yield (Kolota and Osinska, 2001).

Plant height, leaf chlorophyll, fresh and dry weight of herbs/plant and essential oil percentage of *Cymbopogon citratus* were more affected by Lithovit treatments as compared to control (Ghatas and Mohamed, 2018).

Therefore, the aim of this work was to improve the productivity and quality of coriander plants by using the suitable NPK rate and Lithovit concentration under clay soil conditions.

Materials and Methods

This experiment was carried out during the two consecutive seasons of 2016/2017 and 2017/2018 at Ghazalla Experimental Farm, Fac. Agric., Zagazig Univ., Egypt to study the effects of different rates of NPK fertilizers, concentrations of Lithovit and their interaction treatments on growth, yield, chemical constituents and volatile oil production of coriander plants.

Coriander fruits were kindly supplied from Department of Medicinal and Aromatic Plants, HRI, ARC, Giza, Egypt. Fruits were sown directly in soil on 12th and 18th October during the first and second seasons, respectively. The experimental unit area was 2.5 × 3.6 m^2. Each experimental unit contained six ridges with 2.5 m long. The distance between ridges was 60 cm and distance between plants in the same ridge was 30 cm in the two sides of the ridge. About 5-7 fruits were sown per hill, and then thinned after three weeks to two plants/ hill. All agricultural practices were carried out as recommended. The mechanical and chemical properties of the experimental farm soil are shown in Table 1.

Table 1: Physical and chemical properties of the experimental farm soil (average of the two seasons)

Mechanical analysis			Soil texture
Clay (%)	Silt (%)	Sand (%)	Clay
40.50	33.20	26.30	

Chemical analysis												
pH	E C m.mohs / cm	Organic matter (%)	Soluble cations (meq. / l)				Soluble anions (meq. / l)			Available (ppm)		
			Mg^{++}	Ca^{++}	K^{+}	Na^{+}	Cl^{-}	HCO_3^{-}	SO_4^{--}	N	P	K
7.88	1.3	2.05	2.8	1.5	1.3	3.8	4.5	1.5	3.4	280	70	350

This experiment was consisted of 16 treatments. These treatments arranged split-plot in a complete randomized design with three replicates. The main plots included four treatments of NPK fertilizer rates (control without NPK addition, 50%, 75% and 100% of recommended rate), while four treatments of Lithovit (0.0, 2, 4 and 6 $gl^{-1)}$ occupied the sub-plots. The recommended rate of NPK was 150:200:50 kg $feddan^{-1}$ of ammonium sulphate (20.5% N), calcium super phosphate (15.5 P_2O_5) and potassium sulphate (48.5% K_2O), respectively. Phosphorus and potassium fertilizers were added during soil preparation as a soil application. Nitrogen fertilizer was divided into three equal portions and added to the soil at 35, 50 and 65 days after sowing. Lithovit was applied three times (30, 50 and 70 days after sowing).

Recorded data:

Growth characteristics:

After 90 days from sowing, twelve random plants from each treatment were used to determine the following growth characteristics; plant height (cm), branch and leaves number per coriander plant, total dry weight/plant (g) and root length (cm).

Yield components:

After 125 days from sowing, at harvesting, the central ridges of each plot were used for yield components determination of coriander plants. Inflorescence number/plant, fruit yield/plant (g) were recorded and fruit yield per feddan (Kg) was calculated.

Volatile oil production:

The volatile oil from air-dried fruits of coriander plant was isolated by hydro distillation for 3 hr in order to extract the essential oils according to Guenther (1961). Also, volatile oil yield per plant (ml) was calculated by multiplying volatile oil percentage by fruit yield per plant. Volatile oil per feddan was calculated by multiplying the volatile oil yield per plant by weight of fruits per feddan for each treatment.

GC/MS analysis of volatile oil

Samples of *Coriandrum sativum* fruits volatile oil obtained from control and $N_3P_3K_3$ and Lithovit at 6 g/l plants during second season were analyzed by using Trace GC1310-ISQ mass spectrometer (Thermo Scientific, Austin, TX, USA) with a direct capillary column TG–5MS (30 m x 0.25 mm x 0.25 µm film thickness). The column oven temperature was initially held at 60°C and then increased by 8°C /min to 210 °C hold for 2 min. increased to the final temperature 320°C by 14°C /min and hold for 2 min. The injector and MS transfer line temperatures were kept at 270, 280°C respectively; Helium was used as a carrier gas at a constant flow rate of 1.2 ml/min. The solvent delay was 3 min and diluted samples of 1 µl were injected automatically using Autosampler AS1300 coupled with GC in the split mode. EI mass spectra were collected at 70 eV ionization voltages over the range of m/z 45–500 in full scan mode. The ion source temperature was set at 200 °C. The components were identified by comparison of their retention times and mass spectra with those of WILEY 09 and NIST 11 mass spectral database (Adams, 2007).

Chemical constituents:

Total nitrogen, phosphorus and potassium percentages were determined in fruits according to Naguib (1969), Hucker and Catroux (1980) and Brown and Lilleland (1946), respectively. In addition, total chlorophyll content (SPAD unit) in leaves was determined by using SPAD- 502 meter (Markwell *et al.,* 1995) and total carbohydrates in fruits were estimated (Dubois *et al.,* 1956).

Statistical Analysis:

Data of the present work were statically analyzed and the differences between the means of the treatments (NPK fertilizers levels and Lithovit concentrations) were considered significant when they were more than the least significant differences (L.S.D) at the 5% level by using computer program of Statistix version 9 (Analytical Software, 2008).

Results and Discussion

1. Plant growth

Fertilizing of coriander plants grown in clay soil with different rates of NPK (0,50,75 and 100 % of recommended rate of NPK) reflect a significant effect on plant growth in both seasons (Tables 2, 3 and 4) in most cases. Plant growth parameters significantly increased with increasing NPK rates up to $N_3P_3K_3$ (100% of RR) in both seasons.

Fertilizing with $N_3P_3K_3$ (100 % of recommended rate, RR) gave the tallest plants and recorded maximum values of number of both branches and leaves/plant, total dry weight/plant and root length at 90 days after sowing in both seasons.

The increases in total dry weight/plant were about 1.12 and 1.07 g/plant for $N_1P_1K_1$ (50% of RR), 4.60 and 3.94 g/plant for $N_2P_2K_2$ (75% of RR) and 6.19 and 6.09 g/plant for $N_3P_3K_3$ (100% of RR) over the $N_0P_0K_0$ (control) in the 1st and 2nd seasons, respectively.

The results were in accordance with the findings of Bhat *et al. (* 1992). Yousef *et al.* (2014) and Kamrozzaman *et al.* (2016) on coriander.

Table 2: Effect of NPK fertilization, Lithovit and their interaction treatments on plant height (cm) and No. of branches/plant of *Coriandrum sativum* plant during both seasons

NPK fertilization level (F)	Lithovit concentration (g/l) (L)									
	Control	2	4	6	Mean (F)	Control	2	4	6	Mean (F)
	Plant height (cm)					Number of branches/plant				
	First season (2016/2017)									
$N_0P_0K_0$	56.67	64.67	62.67	62.67	61.67	6.00	6.67	7.33	8.67	7.17
$N_1P_1K_1$	57.33	64.33	69.00	73.00	65.92	6.33	7.33	8.67	9.00	7.83
$N_2P_2K_2$	61.00	65.33	73.00	76.33	68.92	8.00	10.00	11.33	12.00	10.33
$N_3P_3K_3$	58.67	73.00	75.33	79.33	71.58	8.33	10.67	13.00	14.00	11.50
Mean (L)	58.42	66.83	70.00	72.83		7.17	8.67	10.08	10.92	
LSD at 5 %	(F)= 1.82	(L)= 2.35		(F)(L)= 4.46		(F)= 1.08	(L)= 0.53		(F)(L)= 1.41	
	Second season (2017/2018)									
$N_0P_0K_0$	61.00	64.33	66.67	71.00	65.75	5.67	7.33	8.67	9.33	7.75
$N_1P_1K_1$	62.33	69.33	71.33	74.00	69.25	7.67	8.67	11.33	11.67	9.83
$N_2P_2K_2$	63.00	68.67	74.33	80.33	71.58	8.67	10.67	11.67	13.00	11.00
$N_3P_3K_3$	64.00	77.67	79.00	82.00	75.67	10.00	12.00	13.67	14.67	12.58
Mean (L)	62.58	70.00	72.83	76.83		8.00	9.67	11.33	12.16	
LSD at 5 %	(F)= 1.47	(L)= 1.78		(F)(L)= 3.40		(F)= 0.71	(L)= 0.52		(F)(L)= 1.15	

Recommended rate (RR) : 60,30 and 25 Kg/ fed. respectivily , $N_0P_0K_0$: control , $N_1P_1K_1$: 50 % of RR , $N_2P_2K_2$: 75 % of RR and $N_3P_3K_3$: 100% of RR .

Table 3: Effect of NPK fertilization, Lithovit and their interaction treatments on number of leaves and total dry weight/plant (g) of *Coriandrum sativum* plant during both seasons

NPK fertilization level (F)	Lithovit concentration (g/l) (L)									
	Control	2	4	6	Mean (F)	Control	2	4	6	Mean (F)
	Number of leaves / plant					Total dry weight /plant (g)				
	First season (2016/2017)									
$N_0P_0K_0$	31.67	36.33	37.33	39.67	36.25	8.35	8.99	10.39	12.41	10.03
$N_1P_1K_1$	31.67	37.00	38.67	40.00	36.83	8.72	9.88	12.15	13.87	11.15
$N_2P_2K_2$	37.00	41.33	41.67	42.67	40.67	10.43	13.73	16.30	18.07	14.63
$N_3P_3K_3$	39.33	41.67	46.33	47.33	43.67	13.33	15.73	16.73	19.10	16.22
Mean (L)	34.92	39.08	41.00	42.42		10.21	12.08	13.89	15.86	
LSD at 5 %	(F)= 1.33	(L)= 1.28		(F)(L)= 2.59		(F)= 0.75	(L)= 0.35		(F)(L)= 1.06	
	Second season (2017/2018)									
$N_0P_0K_0$	31.00	37.33	39.67	41.00	37.25	8.55	9.50	10.83	13.20	10.52
$N_1P_1K_1$	34.33	39.33	42.67	43.00	39.83	9.20	10.04	12.46	14.66	11.59
$N_2P_2K_2$	39.67	43.67	43.33	46.00	43.16	10.80	13.20	15.53	18.33	14.46
$N_3P_3K_3$	41.33	44.67	47.67	48.67	45.58	13.88	15.61	17.35	19.60	16.61
Mean (L)	36.58	41.25	43.33	44.67		10.61	12.09	14.04	16.45	
LSD at 5 %	(F)= 1.94	(L)= 1.23		(F)(L)= 2.88		(F)= 0.68	(L)= 0.58		(F)(L)= 1.31	

Recommended rate (RR) : 60,30 and 25 Kg/ fed. respectivily , $N_0P_0K_0$: control , $N_1P_1K_1$: 50 % of RR , $N_2P_2K_2$: 75 % of RR and $N_3P_3K_3$: 100% of RR .

Concerning the effect of Lithovit , spraying coriander plant with Lithovit at different concentrations (2, 4 and 6 g/l) had significant effect on plant growth parameters (Tables 2, 3 and 4). Spraying coriander plants with Lithovit at 6 g/l gave the tallest plant and recorded the highest values of number of both leaves and branches/plant and root length in both seasons. The results are in conformity with the findings of Ghatas and Mohamed (2018) which reflected on total plant dry weight.

The simulative effect of $N_3P_3K_3$ or Lithovit at 6 g/l on total dry weight/plant may be due to that $N_3P_3K_3$ (100% of RR) or Lithovit at 6 g/l increased plant height, number of both leaves and branches and root length (Tables 2, 3 and 4).

Lithovit compound particles contain calcium carbonate (80%), magnesium carbonate (4.6%) and Fe (0.75%). The beneficial effect of this compound is being contains calcium carbonate ($CaCO_3$) decomposes to calcium oxide (CaO) and carbon dioxide (CO_2) in leaves stomato, and this CO_2 increases photosynthesis intensity, leading to increase carbon uptake and assimilation, thereby increasing plant growth (Carmen *et al.,* 2014).

Respecting the effect of interaction, data in Tables 2, 3, and 4 show that the interaction between NPK and Lithovit had significant effect on plant growth parameters of coriander in both seasons.

The interaction between $N_3P_3K_3$ and Lithovit at 4 or 6 g/l recorded the highest values of plant height, No. of branches and leaves/plant and root length in most cases without significant difference between both treatments. While, the interaction of $N_2P_2K_2$ or $N_3P_3K_3$ + 6 g/l Lithovit yielded the heaviest dry weight of plant. Also, the maximum number of inflorescence/plant was obtained by the interaction of $N_3P_3K_3$ + 6 g/l Lithovit.

Table 4: Effect of NPK fertilization, Lithovit and their interaction treatments on root length (cm) and inflorescence number per plant of *Coriandrum sativum* plant during both seasons

NPK fertilization level (F)	Lithovit concentration (g/l) (L)									
	Control	2	4	6	Mean (F)	Control	2	4	6	Mean (F)
	Root length (cm)					Inflorescence number /plant				
	First season (2016/2017)									
$N_0P_0K_0$	12.33	15.00	16.00	18.00	15.33	15.00	17.00	20.00	23.33	18.83
$N_1P_1K_1$	14.00	16.67	18.00	19.67	17.08	16.33	19.33	22.33	26.67	21.17
$N_2P_2K_2$	16.33	18.33	19.67	20.33	18.67	16.33	21.67	25.00	29.67	23.17
$N_3P_3K_3$	18.67	20.33	22.00	23.67	21.17	20.33	24.33	29.67	34.33	27.17
Mean (L)	15.33	17.58	18.92	20.42		17.00	20.58	24.25	28.50	
LSD at 5 %	(F)= 1.01	(L)= 0.81		(F)(L)= 1.72		(F)= 0.52	(L)= 0.89		(F)(L)= 1.63	
	Second season (2017/2018)									
$N_0P_0K_0$	14.67	16.00	15.00	18.33	16.00	15.67	18.33	21.00	25.00	20.00
$N_1P_1K_1$	15.00	16.00	19.33	18.33	17.16	16.00	20.33	23.00	26.00	21.33
$N_2P_2K_2$	16.67	18.67	19.33	21.00	18.91	18.33	24.00	26.00	28.00	24.08
$N_3P_3K_3$	19.00	20.67	20.33	22.67	20.67	19.00	24.67	27.00	32.33	25.75
Mean (L)	16.33	17.83	18.50	20.08		17.25	21.08	24.25	27.83	
LSD at 5 %	(F)= 1.28	(L)= 0.81		(F)(L)= 1.89		(F)= 1.06	(L)= 0.97		(F)(L)= 1.99	

Recommended rate (RR): 60,30 and 25 Kg/ fed. respectivily , $N_0P_0K_0$: control , $N_1P_1K_1$: 50 % of RR , $N_2P_2K_2$: 75 % of RR and $N_3P_3K_3$: 100% of RR .

2- Yield and its components

Data in Table 5 illustrate that increasing of NPK fertilization level was concomitant with significant increase in fruit yield/plant and feddan.

The increases in fruit yield/fed. were about 44.90 and 87.50 kg/fed. for $N_1P_1K_1$ (50%of RR), 172.5 and 209.5 kg/fed. for $N_2P_2K_2$ (75% of RR) and 246.20 and 295.60 kg/fed. for $N_3P_3K_3$ (100% of RR) over the $N_0P_0K_0$ (control) in the 1st and 2nd seasons, respectively. This result is in accordance with those obtained by Bhat *et al.* (1992), Yousef *et al.* (2014) and Kamrozzaman *et al.* (2016) on coriander.

Fruit yield/plant and feddan were gradually enhanced as Lithovit concentration increased. The highest concentration (6 g/l) gained the maximum fruit yield/plant (10.97 g and 10.75 g) and feddan (1023.5 and 1037.6 kg) during both seasons, respectively. This finding is in harmony with those recorded by Ghatas and Mohamed (2018).

Concerning the effect of the interaction, data in Table 5 illustrate that the interaction between $N_2P_2K_2$ or $N_3P_3K_3$ and Lithovit at 6 g/l fed. produced the maximum fruit yield per plant and feddan without significant difference between both them during first season. Also, the same treatments and the interaction of $N_3P_3K_3$ + 4 g/l Lithovit recorded the heaviest yield of fruits per pland and feddan without significant differences among these treatments during second season. According to these results and

from economic point of view it is better to fertilize coriander plants $N_2P_2K_2$ level and spray them with Lithovit at 4 g/l to gain the maximum fruit yield of coriander plants.

Table 5: Effect of NPK fertilization, Lithovit and their interaction treatments on fruit yield per plant (g) and per feddan (kg) of *Coriandrum sativum* plant during both seasons

NPK fertilization level (F)	Lithovit concentration (g/l) (L)									
	Control	2	4	6	Mean (F)	Control	2	4	6	Mean (F)
	Fruit yield / plant (g)					Fruit yield / feddan (kg)				
	First season (2016/2017)									
$N_0P_0K_0$	5.56	7.28	8.50	9.57	7.73	519.2	679.5	793.0	893.5	721.3
$N_1P_1K_1$	5.67	7.93	9.22	10.02	8.21	529.5	740.1	860.5	934.9	766.2
$N_2P_2K_2$	7.16	8.92	10.32	11.91	9.58	668.6	832.5	962.9	1111.3	893.8
$N_3P_3K_3$	8.17	9.37	11.56	12.37	10.37	762.5	874.5	1078.9	1154.2	967.5
Mean (L)	6.64	8.37	9.90	10.97		620.0	781.7	923.9	1023.5	
LSD at 5 %	(F)= 0.42	(L)= 0.35		(F)(L)= 0.74		(F)= 38.8	(L)= 33.0		(F)(L)= 78.9	
	Second season (2017/2018)									
$N_0P_0K_0$	4.93	6.70	8.83	9.73	7.55	460.4	625.3	824.5	908.4	704.7
$N_1P_1K_1$	5.44	8.27	9.85	10.39	8.49	508.0	771.9	919.3	969.4	792.2
$N_2P_2K_2$	7.67	9.12	10.58	11.81	9.79	715.9	850.9	987.8	1102.3	914.2
$N_3P_3K_3$	8.47	10.07	11.92	12.54	10.75	790.9	939.6	1112.5	1170.1	1000.3
Mean (L)	6.63	8.54	10.30	11.12		618.8	796.9	961.0	1037.6	
LSD at 5 %	(F)= 0.17	(L)= 0.31		(F)(L)= 0.85		(F)= 15.5	(L)= 28.6		(F)(L)= 71.8	

Recommended rate (RR) : 60,30 and 25 Kg/ fed. respectively , $N_0P_0K_0$: control , $N_1P_1K_1$: 50 % of RR , $N_2P_2K_2$: 75 % of RR and $N_3P_3K_3$: 100% of RR .

3- Volatile oil production

As shown in Tables 6 and 7 volatile oil percentage as well as yield per plant and feddan were gradually improved as NPK level or Lithovit concentration increased. Moreover, the maximum values of these characters were recorded when plants were fertilized with the highest level of NPK ($N_3P_3K_3$) combined with the highest concentration (6 g/l) of Lithovit during both seasons. This result is in agreement with those announced by Ghatas and Mohamed (2018).

Table 6: Effect of NPK fertilization, Lithovit and their interaction treatments on volatile oil percentage and volatile oil yield/plant (ml) of *Coriandrum sativum* fruits during both seasons

NPK fertilization level (F)	Lithovit concentration (g/l) (L)									
	Control	2	4	6	Mean (F)	Control	2	4	6	Mean (F)
	Volatile oil percentage					Volatile oil yield per plant (ml)				
	First season (2016/2017)									
$N_0P_0K_0$	0.237	0.253	0.277	0.307	0.268	0.013	0.019	0.024	0.030	0.021
$N_1P_1K_1$	0.260	0.283	0.327	0.320	0.297	0.015	0.022	0.030	0.032	0.025
$N_2P_2K_2$	0.267	0.307	0.337	0.350	0.315	0.019	0.028	0.035	0.042	0.031
$N_3P_3K_3$	0.280	0.330	0.360	0.387	0.339	0.023	0.031	0.042	0.048	0.039
Mean (L)	0.261	0.293	0.325	0.341		0.018	0.025	0.032	0.038	
LSD at 5 %	(F)=0.004	(L)= 0.010		(F)(L)=0.018		(F)=0 .0015	(L)=0.0012		(F)(L)= 0.0027	
	Second season (2017/2018)									
$N_0P_0K_0$	0.246	0.240	0.273	0.286	0.261	0.012	0.016	0.024	0.028	0.020
$N_1P_1K_1$	0.263	0.293	0.330	0.340	0.307	0.015	0.024	0.033	0.035	0.027
$N_2P_2K_2$	0.270	0.300	0.343	0.356	0.317	0.021	0.027	0.036	0.042	0.032
$N_3P_3K_3$	0.293	0.346	0.356	0.386	0.345	0.025	0.035	0.043	0.048	0.038
Mean (L)	0.268	0.295	0.325	0.342		0.018	0.0257	0.034	0.038	
LSD at 5 %	(F)= 0.014	(L)= 0.007		(F)(L)= 0.018		(F)= 0.0009	(L)= 0.0012		(F)(L)= 0.0027	

Recommended rate (RR) : 60,30 and 25 Kg/ fed. respectively , $N_0P_0K_0$: control , $N_1P_1K_1$: 50 % of RR , $N_2P_2K_2$: 75 % of RR and $N_3P_3K_3$: 100% of RR .

Table 7: Effect of NPK fertilization, Lithovit and their interaction treatments on volatile oil yield per feddan (l) and total nitrogen percentage of *Coriandrum sativum* fruits during both seasons

NPK fertilization level (F)	Lithovit concentration (g.l) (L)									
	Control	2	4	6	Mean (F)	Control	2	4	6	Mean (F)
	Volatile oil yield per feddan (l)					Total nitrogen percentage				
	First season (2016/2017)									
$N_0P_0K_0$	1.23	1.72	2.19	2.74	1.97	2.09	2.17	2.21	2.25	2.18
$N_1P_1K_1$	1.37	2.09	2.81	2.98	2.31	2.13	2.27	2.38	2.39	2.29
$N_2P_2K_2$	1.78	2.55	3.24	3.88	2.86	2.17	2.32	2.42	2.41	2.33
$N_3P_3K_3$	2.13	2.88	3.88	4.46	3.34	2.23	2.34	2.56	2.77	2.48
Mean (L)	1.63	2.31	3.03	3.52		2.16	2.28	2.39	2.45	
LSD at 5 %	(F)= 0.129	(L)= 0.126		(F)(L)= 0.253		(F)= 0.077	(L)= 0.050		(F)(L)= 0.116	
	Second season (2017/2018)									
$N_0P_0K_0$	1.13	1.50	2.25	2.60	1.87	2.11	2.17	2.23	2.39	2.22
$N_1P_1K_1$	1.33	2.26	3.03	3.29	2.48	2.14	2.23	2.32	2.39	2.27
$N_2P_2K_2$	1.93	2.55	3.39	3.93	2.95	2.19	2.31	2.39	2.47	2.34
$N_3P_3K_3$	2.32	3.25	3.96	4.52	3.51	2.24	2.31	2.64	2.79	2.49
Mean (L)	1.68	2.39	3.16	3.58		2.17	2.25	2.39	2.51	
LSD at 5 %	(F)= 0.105	(L)= 0.108		(F)(L)= 0.214		(F)= 0.028	(L)= 0.032		(F)(L)= 0.063	

Recommended rate (RR): 60, 30 and 25 Kg/ fed. respectively , $N_0P_0K_0$: control , $N_1P_1K_1$: 50 % of RR , $N_2P_2K_2$: 75 % of RR and $N_3P_3K_3$: 100% of RR .

4- GC/MS analysis of *Coriandrum sativum* fruits volatile oil

Analysis of essential oil extracted from coriander fruits obtained from control treatment and $N_3P_3K_3$ + 6 g/l Lithovit (the best treatment for volatile oil production) treatment is shown in Table 8 and Fig. 1. Thirteen compounds were detected in control volatile oil, while sixteen compounds were characterized in $N_3P_3K_3$ + 6 g/l Lithovit treatment volatile oil. These compounds are accounting for 91.2 and 95.87% of the total volatile oil compounds of both treatments, respectively. Linalool was the main component of the volatile oil obtained from both treatments. Generally, fertilizing plants with $N_3P_3K_3$ and spraying them with 6 g/l Lithovit resulted in higher concentration (%) of each oil component compared with control treatment. The striking result is that there are three compounds (alpha-Farnasene, (E)-2-decenal and Decanal) were detected in volatile oil extracted from plants treated with $N_3P_3K_3$ + 6 g/l Lithovit treatment, but not found in control volatile oil.

5- N, P, K and total carbohydrates percentages in fruits

From data presented in Tables 7, 9, and 10 It could be concluded that as NPK level or Lithovit concentration increased, the N, P, K and total carbohydrates percentages increased throughout the range examined. Additionaly, the interaction treatment of $N_3P_3K_3$ + 6 g/l Lithovit was surpassed all other investigated interaction treatments in this regard.

5- Total chlorophyll content (SPAD unit) in leaf tissues

As seen in Table 10 there was a positive linear relationship between NPK fertilization level or Lithovit concentration and total chlorophyll content in leaves. The highest rate of NPK and Lithovit each alone resulted in the maximum accumulation of chlorophyll pigments in leaves. Furthermore, the interaction treatment between the ultimate levels of NPK and Lithovit exceeded all other interaction treatments in this respect.

Table 8: Chemical composition of *Coriandrum sativum* volatile oil as affected by control treatment and $N_3P_3K_3$ and 6 g/l lithovit treatment

Treatments					
Control			$N_3P_3K_3$[a] + lith. (6 g/l)[b]		
Peak No.	Identified compounds	Concentration (%)	Peak No.	Identified compounds	Concentration (%)
1	**alpha-pinene**	1.26	**1**	**alpha-pinene**	1.29
2	**Camphene**	0.47	**2**	**Camphene**	0.52
3	**alpha-Farnasene**	nd [c]	**3**	**alpha-Farnasene**	0.20
4	**beta-Pinene**	0.42	**4**	**beta-Pinene**	0.69
5	**p-cymene**	0.29	**5**	**p-cymene**	0.61
6	**limonene**	0.38	**6**	**limonene**	0.59
7	**gamma-terpinene**	2.01	**7**	**gamma-terpinene**	2.25
8	**linalool**	79.72	**8**	**linalool**	80.99
9	**Citronellal**	0.49	**9**	**Citronellal**	0.60
10	**camphor**	2.07	**10**	**camphor**	2.84
11	**terpinene-4-ol**	0.04	**11**	**terpinene-4-ol**	0.16
12	**alpha-terpineol**	0.21	**12**	**alpha-terpineol**	0.26
13	**geraniol**	1.99	**13**	**geraniol**	2.02
14	**geranyl acetate**	1.85	**14**	**geranyl acetate**	2.18
15	**(E)-2-decenal**	nd [c]	**15**	**(E)-2-decenal**	0.29
16	**Decanal**	nd [c]	**16**	**Decanal**	0.38
Not identified		**8.8**	**Not identified**		**4.13**
Total identified		**91.2**	**Total identified**		**95.87**

[a] Recommended rate (RR) : 60,30 and 25 Kg/ fed. respectivily , $N_3P_3K_3$: 100% of RR .
[b] lith. (6 g/l): lithovit at 6 gram / liter [c] nd: not determine

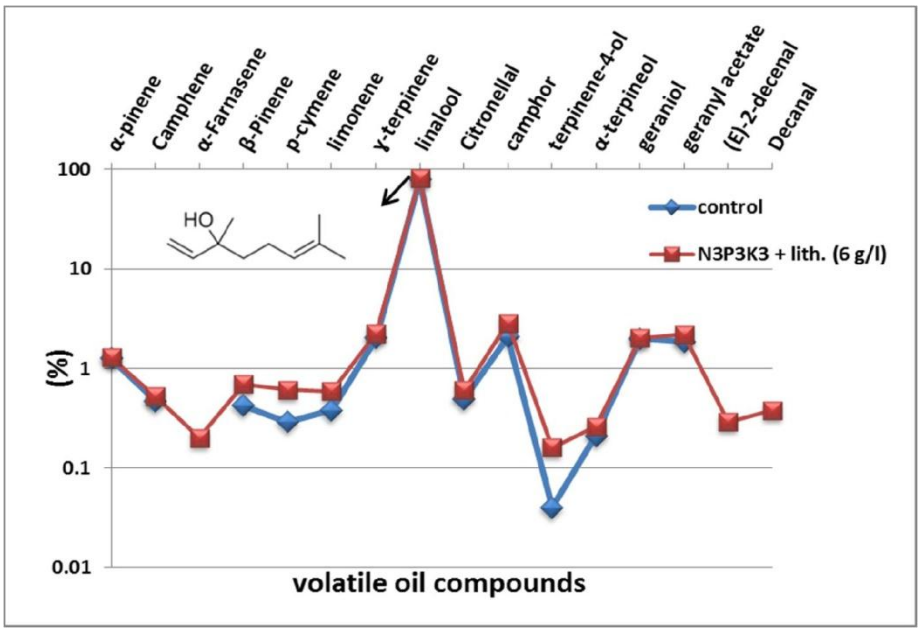

Fig 1: Chemical composition of *Coriandrum sativum* volatile oil as affected by control treatment and $N_3P_3K_3$ and 6 g/l lithovit treatment

Table 9: Effect of NPK fertilization, Lithovit and their interaction treatments on phosphorus and potassium percentages of *Coriandrum sativum* fruits during both seasons

NPK fertilization level (F)	Lithovit concentration (g/l) (L)									
	Control	2	4	6	Mean (F)	Control	2	4	6	Mean (F)
	Phosphorus percentage					Potassium percentage				
	First season (2016/2017)									
$N_0P_0K_0$	0.273	0.326	0.340	0.370	0.327	2.64	2.62	2.90	3.27	2.81
$N_1P_1K_1$	0.320	0.360	0.366	0.383	0.357	2.63	3.16	3.20	3.53	3.13
$N_2P_2K_2$	0.370	0.380	0.400	0.423	0.393	3.33	3.46	3.46	3.63	3.47
$N_3P_3K_3$	0.366	0.376	0.400	0.440	0.395	3.31	3.28	3.60	3.80	3.50
Mean (L)	0.332	0.360	0.393	0.404		2.93	3.13	3.29	3.56	
LSD at 5 %	(F)= 0.007	(L)=0.009		(F)(L)= 0.016		(F)= 0.13	(L)= 0.08		(F) (L)= 0.19	
	Second season (2017/2018)									
$N_0P_0K_0$	0.310	0.320	0.346	0.370	0.336	2.55	2.72	2.94	3.23	2.86
$N_1P_1K_1$	0.350	0.333	0.373	0.376	0.358	2.67	3.21	3.36	3.41	3.16
$N_2P_2K_2$	0.360	0.386	0.396	0.416	0.390	3.35	3.42	3.50	3.56	3.46
$N_3P_3K_3$	0.373	0.383	0.400	0.453	0.402	3.25	3.43	3.73	3.85	3.56
Mean (L)	0.348	0.355	0.379	0.404		2.95	3.19	3.38	3.51	
LSD at 5 %	(F)= 0.012	(L)= 0.009		(F) (L)= 0.019		(F)= 0.06	(L)= 0.08		(F) (L)= 0.15	

Recommended rate (RR) : 60,30 and 25 Kg/ fed. respectively , $N_0P_0K_0$: control , $N_1P_1K_1$: 50 % of RR , $N_2P_2K_2$: 75 % of RR and $N_3P_3K_3$: 100% of RR .

Table 10: Effect of NPK fertilization, Lithovit and their interaction treatments on total carbohydrates in fruits and chlorophyll content (SPAD unit) in leaves of *Coriandrum sativum* during both seasons

NPK fertilization (F)	Lithovit concentration as gram / liter (L)									
	Control	2	4	6	Mean (F)	Control	2	4	6	Mean (F)
	Total carbohydrates percentage					Total chlorophyll content (SPAD unit)				
	First season (2016/2017)									
$N_0P_0K_0$	30.40	30.76	31.50	32.53	31.30	29.00	29.33	31.33	33.67	30.83
$N_1P_1K_1$	31.36	31.90	32.76	34.40	32.60	30.33	33.00	34.00	36.67	33.50
$N_2P_2K_2$	31.10	32.34	34.50	35.14	33.27	30.33	34.33	38.33	40.33	35.83
$N_3P_3K_3$	32.71	33.57	34.68	35.38	34.08	31.67	36.33	39.67	43.00	37.67
Mean (L)	31.39	32.14	33.36	34.36		30.33	33.25	35.83	38.41	
LSD at 5 %	(F)= 0.51	(L)= 0.49		(F) (L)= 0.98		(F)= 0.88	(L)= 0.89		(F) (L)= 1.78	
	Second season (2017/2018)									
$N_0P_0K_0$	30.17	31.39	31.47	32.57	31.40	26.00	28.67	31.67	34.00	31.08
$N_1P_1K_1$	31.30	31.83	32.95	34.51	32.64	30.67	34.33	35.00	36.00	34.00
$N_2P_2K_2$	31.96	32.65	34.17	35.15	33.48	32.33	33.67	37.00	42.00	36.25
$N_3P_3K_3$	32.62	33.17	34.94	35.67	34.10	33.67	36.33	40.33	45.67	39.00
Mean (L)	31.51	32.26	33.38	34.47		30.66	33.25	36.00	39.41	
LSD at 5 %	(F)= 0.33	(L)= 0.30		(F) (L)= 0.62		(F)= 0.97	(L)= 1.20		(F) (L)= 2.29	

Recommended rate (RR): 60,30 and 25 Kg/ fed. respectively , $N_0P_0K_0$: control , $N_1P_1K_1$: 50 % of RR , $N_2P_2K_2$: 75 % of RR and $N_3P_3K_3$: 100% of RR .

Recommendation

Based on our present results it can be concluded that it is recommended to fertilize coriander plants with $N_2P_2K_2$ + 6 g/l Lithovit in order to gain the maximum fruit yield. While, it is advised to apply NPK to coriander plants at the ultimate dose ($N_3P_3K_3$) combined with spraying with Lithovit at 6 g/l to obtain the supreme volatile oil yield under the same experimental conditions.

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