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Effect of Organic and Biostimulants on Yield and Quality of Evening Primrose Oil (*Oenothera biennis* L.)

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ABSTRACT

New biotechnologies that would enable a decrease in the usage of chemical inputs without adversely affecting crop output or farmers' income are being sought after by modern agriculture. Vermicompost and seaweed extract are used as nutrient supplements, organic fertilizers and biostimulants in agriculture and horticulture to increase plant growth and yield. This study was conducted at private farm in Beni-Suef, during the two successive years of 2020/2021 and 2021/2022 to investigate the effects of vermicompost (VC), seaweed extract (SW), and chemical fertilizers on the growth, physiological and yield characteristics of evening primrose. The obtained results show that the combination treatment of vermicompost at 2 tons/fed and seaweed extract at 400 ppm gave the highest values of growth characteristics, seed yield and linoleic acid content of oil.

Key words: Evening primrose (*Oenothera biennis* L.), vermicompost, seaweed extract.

INTRODUCTION

During the Green Revolution era, high-yielding varieties were introduced, irrigated areas were expanded, high analysis NPK fertilizers were used, and cropping intensity increased. During this process, the proportion of organic manures to chemical fertilizers as a source of plant nutrients decreased significantly. Additionally, it has been observed that insect pests are becoming more resistant to chemical insecticides. Numerous studies have documented the presence of multinutrient deficits and an overall decrease in the soil's productive capacity as a result of careless fertilizer application. Such concerns and problems posed by modern-day agriculture gave birth to new concepts in farming, such as organic farming (Madhusudhan, 2017).

Even small additions of vermicompost enhance plant growth and development, and it is a useful tool in horticulture as well as floriculture. Not only do plants become competent, healthy, and productive, vermicompost also organizes plant development by providing hormones and humic acid. Additionally, it improves soil quality and fertility by promoting microbial activity and preventing the spread of diseases and pests that are carried by the soil (Doklega and Imryed, 2020).

In the past few years, biostimulants that is, plant and algae extract or secondary plant metabolites have drawn a lot of attention because they are artificial substances that can boost plant growth, resilience to stress, and yield, which enables them to be incorporated into agricultural production systems (Brown and Saa, 2015). Alga extracts are environmentally focused products that boost the growth and biological yield of many vegetable species, according to numerous reports (Sharma *et al.*, 2014) by strengthening plants' defenses against diseases and stresses. Likewise, multicellular alga "Seaweed" is one of the most marine resources that have been used as a biofertilizer since sixteens of this century. It contains many bioactive substances and plant growth regulators such as auxins, cytokinins, and betaines, as well as considers a cost-effective source for minerals and micronutrients (Craigie, 2011).

Herbs are the main source of medicine for a large portion of the global population. Nowadays, with all of its scientific and technological developments, the world is starting to rediscover the health advantages of herbs and spices that previous generations were so familiar with. These advantages are closely related to a greater understanding of how eating affects one's health and well-being. Numerous medications have been created in pharmacology using herbs and their active ingredients. Evening primrose (*Oenothera biennis* L.) is a plant belonging to the Onagraceae family. It is advantageous for treating a variety of diseases (Murphy *et al.*, 2004).

The production of gamma-linolenic acid (GLA) by plants has drawn more attention in recent years. Native to both North and South America, evening primrose (*Oenothera biennis* L.) is a significant medicinal plant that is grown for its oil seeds because to the high content of γ-linolenic acid (GLA) in its seeds, which has uses pharmacological and nutritional applications. About 20–30% of the seeds' oil is made up of GLA, which is converted by the body into prostaglandin, an important molecule required for healthy cell activity. Consuming GLA has been linked to improvements in a number of chronic conditions, including cardiovascular disease, rheumatoid arthritis, atopic eczema, high blood pressure, and cholesterol (Timoszuk *et al.*, 2018).

The main aim of this research was to examine the effects of seaweed extract and vermicompost on yield and quality of evening primrose plants.

MATERIALS AND METHODS

This study was conducted at private farm in Beni-Suef, 29°04′N 31°05′E during the two seasons of 2020/2021 and 2021/2022.

Oenothera biennis L. seeds were obtained from Agriculture research center. The seeds were sown on 20th October 2020/2021 and 2021/2022 in rows of nursery beds inside a greenhouse. After two months of seed sowing, when the seedlings were 15-20 cm in height, seedlings were transplanted to the plots (2.5 × 3 m) that were prepared in the experimental field, with each plot containing three rows. Each plot included rows that were 2.50 m long and 60 cm apart. Every plot had twelve seedlings., which were cultivated on three rows, at a spacing of 60 cm between rows, and 60 cm between plants within each row. The physical and chemical properties of the soil of the experimental field are shown in Table (1).

Table 1. Physical and chemical analysis of the soil used for growing evening primrose plants during the 2020/2021 and 2021/2022 seasons.

Chemical & physical characteristics	First season	Second season
Clay%	41.36	40.21
Silt%	23.25	23.32
Fine sand%	33.21	34.14
Coarse sand%	2.18	2.33
Soil type	Clay sand	Clay sand
pH	7.11	7.24
N (ppm)	22.4	21.8
P_2O_5 (ppm)	104	106
K_2O (ppm)	167	162
Zn (ppm)	5.22	5.19
Fe (ppm)	2.51	2.88
B (ppm)	2.24	2.27
Mn (ppm)	0.67	0.69
Cu (ppm)	0.48	0.41

In both seasons, the plants were supplied with nine different fertilization treatments. The tested treatments included NPK fertilization, as well as adding vermicompost and Seaweed extract, as follows:

1. Control (the recommended NPK fertilization).
2. vermicompost at 2 ton/fed. (VC1).
3. vermicompost at 4 ton/fed. (VC2).
4. Seaweed extract at 200 mg/l (SW1).
5. Seaweed extract at 400 mg/l (SW2).
6. vermicompost at 2 ton/fed. (VC1). + Seaweed extract at 200mg/l (SW1).
7. vermicompost at 4 ton/fed. (VC2). + Seaweed extract at 200 mg/l(SW1).
8. vermicompost at 2 ton/fed. (VC1). + Seaweed extract at 400 mg/l(SW2).
9. vermicompost at 4 ton/fed. (VC2). + Seaweed extract at 400 mg/l(Sw2).

The recommended NPK fertilization (as described by David *et al.*, 2009) consisted of ammonium nitrate (33%), calcium superphosphate (15.5%) and potassium sulphate (48%), at the rates of 150, 60 and 60 kg/fed., respectively. The ammonium nitrate was divided into two equal doses (one applied 2 weeks after planting the seedlings, and the other applied 4 weeks later), while both calcium superphosphate and potassium sulphate were mixed into the soil one day before planting.

Vermicompost attributes:

During the soil preparation process, vermicompost was added. Table 2 shown the results of the vermicompost chemical analysis.

Table 2. Chemical analysis of vermicompost.

OM%	OC%	N%	C/N	P%	K%	pH	EC dS m^{-1}
35.11	21.08	1.72	1:16	2.18	1.43	7.62	2.17

OM: Organic matter **OC: Organic carbon**

Seaweed extract treatments were sprayed at rate 200 and 400 ppm (SW1 and SW2) until the dripping point. The first seaweed application was added after month from planting, throughout the season, the treatments were repeated every three weeks. The chemical analyses of seaweed extract are shown in table (3).

Table 3. Chemical and biochemical analyses of seaweed extract.

Organic matter				Growth regulators		Macro and micro elements							
Amino acid%	Carbohydrates %	Alginic acid%	Manitol %	IAA%	Cytokinins % (Adenine)	N%	P%	K %	Ca %	S %	Mg %	Fe ppm	Zn ppm
13%	32%	8%	2%	0.06%	0.04%	4.12	2.76	4.8	0.2	3.71	0.63	123	62

Layout of the experiment

According to Snedecor and Cochran (1989), the experiment's design was a randomized complete blocks layout, with 9 fertilization treatments and three replicates (blocks).

1. **Recorded data**

a. **Vegetative growth characteristics (at the stage of 50% flowering)**

In both seasons, the following growth characteristics were recorded when approximately half of the flowers on each plant were open:

1. Plant height.
2. Number of branches/plant.
3. Plant fresh and dry weights (g). Plant dry weight was recorded after drying the plants in an oven at 70° C until a constant weight was reached (after approximately 48 hours).

b. **Seeds production**

The Capsules were collected by hand at the ripening stage, and the following characteristics recorded were:

1. Number of capsules/ plant
2. Capsules dry weight/ plant (g) was recorded after sun-drying of the fruits.
3. Seed weight/plant (g).
4. Seeds weight/ fed. (kg) was calculated by multiplying the seed weight/plant by the number of plants/fed. (11111 plants/fed.).

c. **Fixed Oil production**

1. The fixed oil was extracted from the seeds using the Soxhlet method (as described in the A.O.A.C., 1970), and the following characteristics were calculated:
2. Oil yield (g/plant) was calculated by multiplying the seeds dry weight by the oil percentage.
3. Oil yield (kg/fed.) was calculated by multiplying the oil yield/plant by the number of plants /feddan.
4. The fatty acid content in the oil was determined using gas chromatography (GC) according to (Adams, 2007).

d. **Determination of some chemical constituents:**

1. Determination of total chlorophyll (mg/g/f.w.) according to Rodriguez and Miller (2000).
2. **NPK determinations:** Included in the mineral content were the percentages of nitrogen (measured using the Kjeldhal method as reported by Hach *et al.*, (1985), phosphorus calculated using by A.O.A.C., (1970), and potassium (determined using a flame photometer using by Brown and Lilleland, (1946) method.

RESULTS AND DISCUSSION

a. Growth characteristics:

Results recorded during both seasons (Table 4) demonstrate that chemical NPK fertilization had a more pronounced effect on increasing growth characteristics of *Oenothera biennis* plants (plant height, number of branches per plant, fresh and dry weight/plant) in comparison to the addition of Vermicompost or seaweed extract individually.

However, combining vermicompost and seaweed extract gave better results than those from NPK fertilization. In both seasons, using the combination of VC1 and SW2 gave the tallest plants 111 cm and 123.21 cm, the highest branches number per plant 30.50 and 32.94 branches/plant, plant fresh weight 1190.63 and 1798.57g and dry weight of plant 401.72 and 547.30 g in the first and the second seasons, respectively.

Moreover, a rise in the amount of organic matter in the soil stimulates biological activity, which raises the concentration of nutrients that are accessible for plant roots to absorb. This has a favorable impact on the production of chlorophyll, vegetative development, and crop quantity. These outcomes align with the ones obtained by Arancon and Edwards (2005); Tejada *et al*. (2006) and Frasetya *et al*. (2019).

In connection, similar results indicated that foliar applications of seaweed extract increased growth of canola (Ferreira and Lourens, 2002) and sweet pepper (Arthur *et al.*, 2003). Many reports mentioned that biostimulants improve growth and development of sprayed plants by increasing carbon and nitrogen metabolism (Gonzalez *et al.*, 2014), photosynthesis as well as enhancing nutrients uptake from the soil (Halpern *et al.*, 2015).

Table 4. Effect of NPK, vermicompost and seaweed extract on growth characteristics of evening primrose plants throughout the 2020/2021 and 2021/2022 seasons.

Treatments	Plant height (cm)		Branches number/plant		Fresh weight/plant (g)		Dry weight/plant (g)	
	First season	Second season	First season	Second season	First season	Second season	First season	Second season
NPK	101.01	113.22	21.96	24.40	796.65	1179.35	215.05	308.59
VC1	88.80	100.64	12.20	14.24	633.93	882.90	179.64	247.12
VC2	93.24	103.97	16.67	20.74	693.43	936.39	194.83	271.26
SW1	84.36	89.17	7.32	10.58	253.12	477.23	67.90	126.35
SW2	87.69	95.83	10.98	16.26	358.58	622.63	96.11	171.65
VC1+SW1	103.23	118.03	26.84	30.90	1023.02	1563.92	339.31	528.18
VC2+SW1	107.30	122.47	29.28	31.72	1159.38	1756.02	384.46	569.08
VC1+SW2	111.00	123.21	30.50	32.94	1190.63	1798.57	401.72	603.04
VC2+SW2	112.08	119.51	28.06	29.28	1106.27	1720.99	361.34	547.30
L.S.D. at 0.05	**3.32**	**4.11**	**2.32**	**2.76**	**19.23**	**21.09**	**7.72**	**10.56**

NPK= ammonium nitrate, calcium superphosphate and potassium sulphate at 150, 60 and 60 kg/fed., respectively - VC1, VC2= Vermicompost at 2 and 4 ton /fed., respectively - SW1, SW2= Seaweed extract at 200 and 400 mg/L, respectively.

b. Seeds production:

Results observed in the two seasons (Table 5) showed that fertilization of evening primrose plants with NPK had a significantly superior effect on developing capsules number per plant with values 616.37 and 629.07g, capsules dry weight per plant 124.76 and 139.46 g, seed weight per plant 111.88 and 126.91 g and seed yield per feddan 1243.10

and1410.10 kg in both seasons respectively, compared to vermicompost or seaweed extract individually.

While, capsules number per plant, capsules dry weight per plant and seed weight per plant were significantly increased (in both seasons) by supplying the plants with combinations of VC1 + SW1, VC2 + SW1, VC1+ SW2 or VC2+SW2 compared to NPK fertilization. Among the different tested double treatment combinations, the most effective one for increasing capsules number per plant 869.86 and 906.45, capsules weight per plant 276.79 and 317.60 g, seeds weight per plant 193.06 and 219.47g and seed yield per feddan 2145.09 and 2438.53 kg were supplying the plants with VC1 + SW2 in both seasons.

In our investigation Seaweed extract application promoting evening primrose vegetative growth, yield and its components, these enrichments in the previous characters due to seaweed extract content with high levels of organic matter, microelements, vitamins and amino acids and also has a high concentration of growth regulators like gibberellins, cytokinins, and auxins (Khan *et al.*, 2009). It has previously been demonstrated that exogenous application of seaweed extract increases growth, yield, and quality of plants, as well Shehata *et al.* (2011) on Celeriac plant. Vermicompost gives nutrients to plants that are readily absorbed. It provides auxins, which are plant growth hormones that can be produced during the fermentation process and may be the reason for the growth increases and seed yield. These findings were derived from a perspective akin to that which was published by Edwards *et al.* (2007) and Massoud *et al.* (2022). The beneficial effects of vermicompost and seaweed extract on *Oenothera biennis* seed production may be attributed to the release of nutrients from vermicompost into the soil. In addition, seaweed has a promotive effect on plants; it has been reported to be an enriched source for cytokinins, vitamins, enzymes, amino acids and minerals. It also releases CO_2, which promotes better plant growth and increases net photosynthesis in plants. Karimi *et al.* (2011) reported that application of vermicompost significantly increased corn yield compared with control treatment. Furthermore, Amin *et al.* (2010) showed that vermicompost is a more effective organic fertilizer than other ones for increasing the grain yield of castor beans.

Table 5. Effect of NPK, vermicompost and seaweed extract on number of capsules/ plant (g), capsules dry weight/ plant (g), seed weight/plant (g) and seed yield/fed. (kg) on evening primrose plants throughout the 2020/2021 and 2021/2022 seasons.

Treatments	Number of capsules/ plant (g)		Capsules dry weight/ plant (g)		Seed weight/plant (g)		Seed yield/fed. (kg)	
	First season	Second season	First season	Second season	First season	Second season	First season	Second season
NPK	616.37	629.07	124.76	139.46	111.88	126.91	1243.10	1410.10
VC1	392.00	401.33	66.88	92.85	59.30	68.83	658.88	764.77
VC2	437.54	493.92	98.51	104.77	70.60	83.06	784.44	922.88
SW1	210.56	222.13	29.75	34.83	21.26	26.13	236.22	290.33
SW2	291.20	299.04	54.32	58.65	32.34	37.17	359.33	413.00
VC1+SW1	688.80	730.24	205.93	232.34	138.97	162.10	1544.10	1801.09
VC2+SW1	804.53	845.23	248.24	285.25	178.59	196.10	1984.31	2178.87
VC1+SW2	869.86	906.45	276.79	317.60	193.06	219.47	2145.09	2438.53
VC2+SW2	772.05	833.28	224.35	249.10	160.96	190.52	1788.43	2116.87
L.S.D. at 0.05	**15.83**	**11.31**	**7.22**	**9.53**	**4.89**	**8.61**	**102.59**	**112.16**

NPK= ammonium nitrate, calcium superphosphate and potassium sulphate at 150, 60 and 60 kg/fed., respectively - VC1, VC2= Vermicompost at 2 and 4 ton /fed., respectively - SW1, SW2= Seaweed extract at 200 and 400 mg/L, respectively.

c. Fixed Oil production:

Data reported in Table (6) revealed that fertilization of evening primrose plants with NPK gave better effect on increasing fixed oil percentage with values 16.46% and 18.18 %, oil yield per plant 18.42 and 23.07 g and oil yield per feddan 204.66 and 256.33 kg in both seasons, in comparison to vermicompost or seaweed extract independently.

The combination of VC1 and SW2 gave higher fixed oil percentage 22% and 23.71%, oil productivity per plant of 42.47 and 52.03 g/plant and oil yield per fedaan 471.88 and 578.11 kg compared to NPK treatment in the both seasons, respectively. The results concur with the findings of Badr *et al.* (2013) on *Helianthus annuus*, who discovered that plants that got organic fertilization produced the highest seed oil yield per plant. Vermicompost performs well as a bio-control agent and organic fertilizer because it provides organic nutrients and promotes plant growth. (Simsek, 2011). Oil yield and content can be increased by 10 ton ha^{-1} vermicompost (Mohammadi *et al.*, 2012). Sesame oil yield also increases because of vermicomposting (Sajadi *et al.*, 2011). Ardebili *et al.* (2012) discovered that applying seaweed extract at appropriate doses as a source of amino acids improved oil content.

Table 6. Effect of NPK, vermicompost and seaweed extract on fixed oil percentage oil yield/plant (g) and oil yield/fed. (kg) on evening primrose plants throughout the 2020/2021 and 2021/2022 seasons.

Treatments	Fixed oil percentage		Oil yield/ plant (g)		Oil yield/fed. (kg)	
	First season	Second season	First season	Second season	First season	Second season
NPK	16.46	18.18	18.42	23.07	204.66	256.33
VC1	14.90	16.53	8.84	11.38	98.22	126.44
VC2	15.89	15.80	11.21	13.13	124.55	145.89
SW1	12.19	12.88	2.59	3.37	28.78	37.44
SW2	13.10	13.59	4.24	5.05	47.11	56.11
VC1+SW1	19.92	22.01	27.68	35.68	307.55	396.44
VC2+SW1	21.11	22.91	37.69	44.92	418.77	499.11
VC1+SW2	22.00	23.71	42.47	52.03	471.88	578.11
VC2+SW2	20.21	21.05	32.54	40.11	361.55	445.66
L.S.D. at 0.05	**0.65**	**0.53**	**1.67**	**1.83**	**8.21**	**9.34**

NPK= ammonium nitrate, calcium superphosphate and potassium sulphate at 150, 60 and 60 kg/fed., respectively - VC1, VC2= Vermicompost at 2 and 4 ton /fed., respectively - SW1, SW2= Seaweed extract at 200 and 400 mg/L, respectively.

Fatty acid analysis with GC:

The type and quantity of fatty acids in oilseed indicate the oil's quality. Evening primrose is a good source of oleic or monoulinoleic and linolenic acid or polyunsaturated fatty acids.

Results of the chromatographic analysis of fixed oil samples extracted from (*Oeonthera beinnis* L.) plants in the second season (Table 7 and Figures 1 to 9) show that, linoleic acid was the most important fixed oil component (with contents of 63.30 – 66.20%), followed by γ-linolenic acid (with contents of 7.22 -14.61%), and oleic acid% (with contents of 10.16 - 12.32%). Also, the saturated and unsaturated fatty acids in evening primrose oil were higher with NPK treatment, compared to VC or SW individually. Combining VC1 and SW2 gave the highest unsaturated fatty acid content (92.40%), but gave the lowest saturated fatty acid content (4.65%).

On the other hand, vermicompost at rate 4 ton/fed., gave higher linoleic acid (65.13%) than all concentrations of seaweed extract. Regarding the effect of double treatment combinations, it can be seen that the combination of VC1+SW gave the highest unsaturated fatty acid content (91.41%). In most cases, the linoleic acid and γ-linoleic acid contents in the oil of *Oenothera beinnis* were higher with the NPK treatment (with values 64.71% and 10.40%

respectively), compared to VC or SW independently. Plants treated with the VC1+SW2 gave higher linoleic acid and γ-linolenic acid contents (66.20% and 14.61%, respectively), compared to other treatments. According to Mohammadi *et al*. (2011), linoleic and oleic acid content of rapeseeds was considerably raised by applying vermicompost as opposed to artificial fertilizers. Monir *et al.* (2007) found that compared to the control, the variation containing 40 t/decare of vermicompost has a less noticeable rise in linoleic acid content, reaching 76.70%.

Table (7). Effect of NPK, vermicompost and seaweed extract on fatty acids of evening primrose oil throughout the first season (2020/2021).

Treatments	Component							
	Saturated fatty acids (%)			Unsaturated fatty acids (%)				Total fatty acids (%)
	Palmetic acid	Stearic acid	Total	Oleic acid	Linoleic acid	γ-Linolenic acid	Total	
NPK	8.10	1.67	**9.77**	10.16	64.71	10.40	**85.27**	**95.04**
VC1	8.47	0.95	**9.42**	11.16	63.67	7.53	**82.35**	**91.78**
VC2	5.98	2.07	**8.04**	11.60	65.13	7.22	**83.95**	**91.99**
SW1	7.61	1.47	**9.08**	10.53	63.30	8.54	**82.37**	**91.45**
SW2	7.08	0.74	**7.81**	10.64	64.62	8.46	**83.71**	**91.53**
VC1+SW1	5.57	1.03	**6.60**	11.42	64.86	12.95	**89.23**	**95.83**
VC2+SW1	5.15	0.66	**5.81**	12.32	65.06	13.36	**90.75**	**96.56**
VC1+SW2	3.45	1.20	**4.65**	11.59	66.20	14.61	**92.40**	**97.05**
VC2+SW2	3.92	1.51	**5.44**	11.98	64.56	13.58	**90.12**	**95.56**

NPK= ammonium nitrate, calcium superphosphate and potassium sulphate at 150, 60 and 60 kg/fed., respectively - VC1, VC2= Vermicompost at 2 and 4 ton /fed., respectively - SW1, SW2= Seaweed extract at 200 and 400 mg/L, respectively.

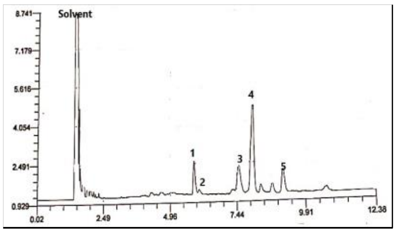

Fig.1. Chromatogram of the fatty acid of plants treated with NPK.

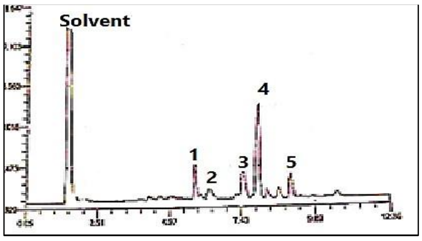

Fig.1. Chromatogram of the fatty acid of plants treated with NPK.

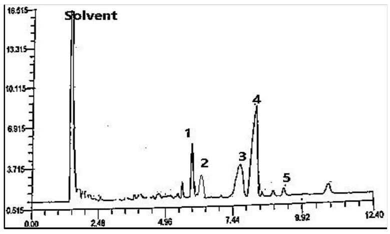

Fig.3. Chromatogram of the fatty acid of plants treated with VC2.

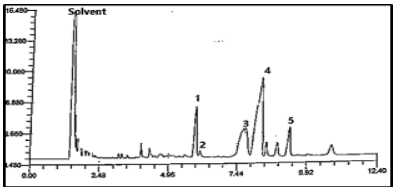

Fig.4. Chromatogram of the fatty acid of plants treated with SW1.

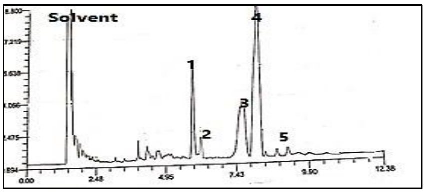

Fig.5. Chromatogram of the fatty acid of plants treated with SW2.

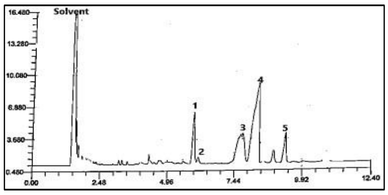

Fig.6. Chromatogram of the fatty acid of plants treated with VC1+SW1.

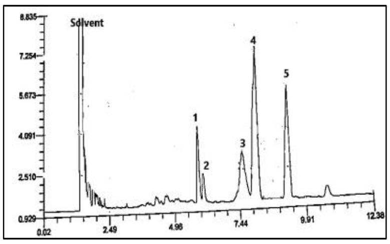

Fig.7. Chromatogram of the fatty acid of plants treated with VC1+SW2.

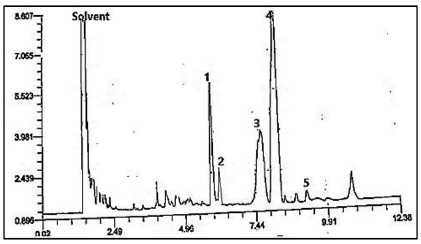

Fig.8. Chromatogram of the fatty acid of plants treated with VC2+SW1.

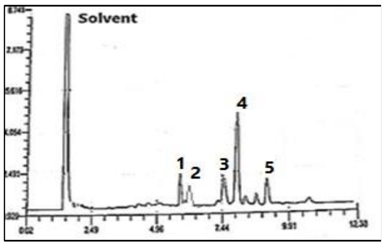

Fig.9. Chromatogram of the fatty acid of plants treated with VC2+SW2.

1. Palmetic acid (C16:0) 2. Stearic acid (C18:0) 3. Oleic acid (C18:1) 4.Linoleic acid (C18:2) 5. γ-Linolenic acid (C18:3)

d. chemical constituents:

1. Total chlorophyll (mg/g F.W.) in leaves:

According to the data presented in Table (8) and, NPK fertilizer increased total chlorophyll content more effectively of *Oenothera biennis* L. plants with values 1.75 and 1.96 mg/g F.W in both seasons, compared to the addition of VC or SW independently.

Also, the addition of double combination of VC and SW gave superior results than the NPK treatment. The double combination of VC1+SW2 gave the highest total chlorophyll content, with values of 1.15 and 1.62 mg/g F.W. in the first season and the second seasons, respectively. Similar results were obtained by El-Shayeb (2009) and El-Hanafy *et al.*, (2016) on *Oenothera biennis* L.and Mathivanan *et al.* (2012) on *Arachis hypogaea*, who found that organic manure increased chlorophyll content. Also, seaweed extract helps treated plants to accumulate more photosynthetic pigments (Taha and Abdelaziz, 2015).

2. Percentages of nitrogen, phosphorus and potassium:

The data recorded in both seasons (Table 8) reveal that, the nitrogen, phosphorus and potassium content varied considerably among plants receiving the different treatments. In both seasons, NPK gave the highest N, P and K content in leaves, with values of 3.37%, 3.41%, 0.47%, 0.46%, 2.84% and 2.74% in both seasons, respectively. On the other hand, the lowest N, P and K contents (with values of 2.17%, 2.15%, 0.34, 0.37, 1.42% and 1.60%, in the first and the second seasons) was obtained by SW1.

It can also be seen that, the double treatment combination of VC1+SW2 gave a higher N, P and K contents which recorded 3.74%, 4.07%, 0.54%, 0.55%, 3.40% and 3.48% during in the first and the second seasons, respectively, compared to NPK or any other treatment.

Vermicompost increases the rate of mineralization and the amount of elements that are available for plant roots to absorb from the soil. It also raises the concentration of CO2 in the soil solution, which lowers the soil's alkalinity and promotes growth by enabling roots to absorb more nutrients, which increases the amount of N, P, and K that are subsequently absorbed by the plant tissues. Furthermore, an increase in chlorophyll content increases the efficiency of the photosynthesis process. These results confirm those obtained by Frasetya *et al.*, 2019. It is already known that applying seaweed extract exogenously can improve plant development, stimulate the production of chlorophylls, and increase the uptake of N, P, K, Mg, Ca, Zn, Fe and Cu by plants (Mahdy *et al.*, 2022).

Table (8). Effect of NPK, vermicompost and seaweed extract on total chlorophyll (mg/g. F.W) in leaves, N, P and K% in dry matter of evening primrose throughout the 2020/2021 and 2021/2022 seasons.

Treatments	Total chlorophyll (mg/g.f.w.)		N% of dry matter		P% of dry matter		K% of dry matter	
	First season	Second season	First season	Second season	First season	Second season	First season	Second season
NPK	1.75	1.96	3.37	3.41	0.47	0.46	2.84	2.74
VC1	1.58	1.61	2.50	2.49	0.38	0.39	1.81	1.90
VC2	1.54	1.57	2.70	2.87	0.41	0.40	2.09	2.17
SW1	1.35	1.37	2.17	2.15	0.34	0.37	1.42	1.60
SW2	1.39	1.42	2.33	2.41	0.31	0.36	1.57	1.69
VC1+SW1	1.91	2.33	3.48	3.70	0.47	0.50	3.36	3.00
VC2+SW1	2.03	2.48	3.63	3.83	0.49	0.53	3.35	3.05
VC1+SW2	2.15	2.62	3.74	4.07	0.54	0.55	3.40	3.48
VC2+SW2	2.01	2.45	3.45	3.73	0.52	0.54	3.19	3.21
L.S.D. at 0.05	**0.24**	**0.36**	**0.26**	**0.38**	**0.03**	**0.05**	**0.43**	**0.56**

NPK= ammonium nitrate, calcium superphosphate and potassium sulphate at 150, 60 and 60 kg/fed., respectively - VC1, VC2= Vermicompost at 2 and 4 ton /fed., respectively - SW1, SW2= Seaweed extract at 200 and 400 mg/L, respectively.

Conclusions:

It could be recommended that, for commercial production, Evening Primrose (*Oenothera biennis* L.) plants should be fertilized with a combination of vermicompost at the rate of 2 ton/fed. and seaweed 400 ppm. This combination had favourable effect on the seed yield, oil productivity, as well as the Linoleic acid and γ-Linolenic acid contents.

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