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Original Article

GROWTH, YIELD AND FATTY ACIDS RESPONSE OF *OENOTHERA BIENNIS* TO WATER STRESS AND POTASSIUM FERTILIZER APPLICATION

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ABSTRACT

Objective: The objective of this research was to study the effects of water stress treatments (40, 60, and 80 % available soil moisture, ASM) and/or potassium application (0, 0.4 and 0.8 g/pot) on growth parameters, yield and fatty acids content and composition of *Oenothera biennis* under greenhouse conditions.

Methods: A two years pot experiment was conducted on *Oenothera biennis* under Egypt conditions in 2013/2014 and 2014/2015 seasons. Growth, seed yield (g/plant) and seed fixed oil content recorded at the first and second seasons. The fatty acid profile of total lipids extracted from *Oenothera biennis* was determined by Gas-liquid chromatography (GLC) analysis.

Results: Growth characteristics (plant height, the number of branches, the number of capsules/plant and dry weights of the whole plant, root, and straw), seed yield (g/plant) and oil yield in two seasons were significantly decreased with the rise in water stress levels. Oil % was stimulated in response to water stress. Application of potassium counteracted the adverse effects of water stress. The maximum growth, seed yield and oil yield were obtained from plants irrigated with 80 % available soil moisture (ASM) plus potassium (0.8 g/pot). On the contrary, supplying plants with a water level of 40 % ASM and with potassium (0.8 g/pot) or (0.4 g/pot) gave the best result for the oil percentage in the first and second seasons, respectively. In respect to fatty acids profile, the percentage of C16:0, C18:1n9 and C22:0 acids were increased with increasing water stress while a reverse response was observed in C18:0, C18:2n6, C20:0, C18:3n6 and C20:1n9 acids. K application attenuated oil composition, where it led to a slight increase in C18:2n6 and C20:0 acids while decreased the percentages of C16:0, C18:1n9, C22:0 acids C18:0, C18:3n6 and C20:1n9 acids. Potassium rates plus 60 % ASM increased C18:0 and C18:1n9 acids while K application with both of 60 % ASM and 40 % ASM increased C18:2n6 and C20:0 acids. The C22:0 acids increased under the interaction of all irrigation treatments with (0.4 g/pot) dose of K. However, C16:0 acids increased as a result of 80 % ASM treatment with the different potassium rates. This study demonstrated the beneficial effects of K application to alleviating the adverse effects of water stress on *Oenothera* plants.

Conclusion: Increasing irrigation levels increased the plant height, the number of branches, the number of capsules/plant, seed yield and dry weights of the whole plant, root, and straw of *Oenothera biennis* and the optimum irrigation level for the highest yields of these variables was 80 % ASM. Whereas, oil % decreased with increasing irrigation levels and the optimum irrigation level for the highest oil % was 40 % ASM. However, for the oil yield from plants that received 80 % ASM produced more oil yield than plants received 60 % or 40 % ASM. Application of potassium counteracted the adverse effects of water stress. Potassium fertilizer increased plant height, the number of branches, the number of capsules/plant, seed yield and dry weights of the whole plant, root, and straw of *Oenothera biennis.* Application of potassium could be a practical approach for enhancing the oil accumulation in *Oenothera biennis*. The current study provided important information about the qualitative and quantitative changes in the fatty acids profile of *Oenothera biennis* in relation to potassium application under water stress conditions.

Keywords: Fatty acids, *Oenothera biennis*, Potassium fertilizer, Water stress

INTRODUCTION

Water deficiency and inadequate mineral nutrients supply are major environmental problems due to the increase in world population and intensive use of natural resources. These environmental stresses contribute significantly to the reduction in crop productivity depending on the severity of stress, species, and other environmental factors. Water deficit in plants may lead to physiological disorders, such as a reduction in photosynthesis and transpiration [1] and may cause significant changes in the yield and composition of fixed oils as was previously found in various plants, such as canola [2] and sunflower [3].

Mineral-nutrient status of plants plays a critical role in increasing plant resistance to environmental stress factors [4]. One of the essential elements, which play a particular role in plant response to water stress, is potassium. Potassium (K^+) has a substantial effect on enzyme activation, protein synthesis, photosynthesis, stomatal movement and water relation (turgor regulation and osmotic adjustment) in plants [4]. K is a predominant accumulating solute during drought and significantly contributes to osmotic adjustment in plants [5, 6]. Increased application of K has been shown to enhance photosynthetic rate, plant growth, yield, and drought resistance in different crops under water stress conditions [7-9]. Under water stress, K-fed plants usually maintain higher leaf water potential, turgor potential, and relative water content and lower osmotic potential as compared to untreated plants [10, 11].

In recent years, there has been increased interest in plants that produce gamma-linolenic acid (GLA). Evening primrose (*Oenothera biennis* L.) is an important medicinal plant native to North America and South America and is cultivated as an oil seed crop because its seeds are rich in γ-linolenic acid (GLA), which is used in both nutritional and pharmaceutical applications [12-14]. The seeds contain about 20-30 % oil with approximately 7-10 % GLA, which is transformed in the body into the important prostaglandin that is essential for the proper functioning of cells [15]. GLA intake has been associated with the improvement in some chronic diseases such as rheumatic arthritis, atopic eczema, cardiovascular disease, high blood cholesterol and high blood pressure [13, 16].

It is known that growth, yield and the content of seed oil and the fatty acid composition could be affected by environmental factors. Previous studies on evening primrose have shown that plant growth, and seed oil content was influenced by various environmental stresses [17-19]. Despite its importance as a promising oil crop in Egypt, there is a missing gap in the literature regarding the response of evening primrose to water stress as well as the factors that might enhance its productivity. Specifically, we aimed to investigate the effect of water stress levels and K rates on *Oenothera biennis* growth, yield, seed oil and fatty acids composition under greenhouse conditions.

MATERIALS AND METHODS

Plant material and growing conditions

A pot experiment was carried out under greenhouse conditions at the National Research Center, Dokki, Giza, Egypt, during the two successive seasons of 2013/2014 and 2014/2015. Seeds of *Oenothera biennis* were obtained from Medicinal and Aromatic Research Dept., Ministry of Agriculture, Egypt. The seeds were sown on 15th of November, during both seasons in pots of 30 cm diameter containing 10 kg of air-dried soil. The physical and chemical analyses of the soil were conducted according to Jackson [20].

The soil texture consisted of: 45.0 % sand, 28.25 % silt, 26.75 % clay and 0.85 % organic matter. Chemical analysis of the soil showed: pH = 8.40; E. C. = 0.79 ds/m; total nitrogen = 0.13 %; available phosphorus = 2.18 mg/100gram; potassium = 0.02 mg/100gram. Field capacity (FC) and wilting point (WP) were determined after the methods of Black [21]. Two-season means of field capacity, permanent wilting point, available soil moisture (ASM), and bulk density (BD), were 34.50 %, 16.01 %, 18.49 % and 1.36 g/cm^3, respectively. Potassium sulphate (48 % K2SO4) was applied at 4 wk post weeks showing at the rate of 0.0 (K0), 0.4 (K1) and 0.8 (K2) g/pot. After one month and a half from sowing, irrigation treatments were at 80 % (I1), 60 % (I2) and 40 % (I3) ASM, which were equal to 30.8., 27.10 and 22.61 ASM, respectively. Pots were weighed daily. When the percent of soil moisture reached the above levels, pots were irrigated to reach field capacity (34.50 % soil moisture). The differences between the needed soil moisture for the previous treatments and field capacity were calculated and added to the pots in the different treatments. The experimental layout was factorial in a completely randomized design, with three replications. Each replicate contained 10 pots of 2 plants each.

Morphological characteristics

Plants were harvested on the 20th of May in both seasons at full fruits ripening by uprooting the plants from the soil by hand. Plant morphological characteristics including plant height, the number of branches, dry weights of root and straw and the number of capsules/ plant and seed yield (g/plant) were measured and recorded.

Extraction of seed oil

Oenothera biennis seeds were crushed and ground with a grinding mill (Petra electric, Burga, Germany). The oil was extracted from the ground material with n-hexane at 50-60 °C in a Soxhlet apparatus for 6 h following the AOCS method [22]. The total lipids content was determined as a percentage of the extracted total lipids to the sample weight (w/w). The oil obtained was stored at 4 °C for further investigation.

Gas-liquid chromatography (GLC) analysis of fatty acid methyl esters (FAME)

The fatty acid profile of total lipids extracted from *Oenothera biennis* was determined following the International Organization of Standards (ISO) [23]. One drop of oil was dissolved in 1 mL of n-heptane, then 50 µL of 2 M sodium methanolate in methanol was added, and the closed tube was agitated vigorously for 1 min. The tube was centrifuged at 45000g, after addition of 100 µL of water, for 10 min and the lower aqueous phase was removed. Fifty µL of 1 M HCl was added to the n-heptane phase; the two phases were mixed, and the lower aqueous phase was discarded. About 20 mg of sodium hydrogen sulphate (monohydrate, extra pure, Merck, Darmstadt, Germany) was added, and after centrifugation at 45009g for 10 min, the top n-heptane phase was transferred into a vial and injected into a Varian 5890 gas chromatograph equipped with CP-Sil 88 capillary column, (100 m long, 0.25 mm ID, and 0.2 µm film thickness). The temperature program was: from 155 °C to 220 °C (1.5 °C/min.), 10 min isotherm; injector 250 °C, detector 250 °C; carrier gas 1.07 ml/min hydrogen; split ratio 1:50; detector gas 30 ml/min hydrogen; 300 ml/min air and 30 ml/min nitrogen and manual injection less than 1 µL. The integration software computed the peak areas, and percentages of FAME were obtained as weight percent by direct internal normalization.

Statistical analysis

Except for the constituents of the fatty acids, the data in this study were analyzed with the analysis of variance (ANOVA) using JMP 10 program (SAS Institute, NC, USA). The mean values of treatments were compared using Tukey's HSD test. Values accompanied by different letters are significantly different at $p \leq 0.05$.

RESULTS AND DISCUSSION

Growth parameters and yield

Tables (1and 2) indicate that decreasing irrigation water to 40 % ASM significantly decreased plant height, the number of branches, the number of capsules/plant, seed yield, oil yield and dry weights of the whole plant, root, and straw in the two seasons. Exceptions are the number of branches in the 1st season and plant height in the 2nd season, which were not affected by irrigation water. Generally, irrigation at 80 % ASM resulted in the highest.

Values of these parameters, while 40 % treatment resulted in the lowest values. These results are in conformity with some previous results, For instance, Rezaei *et al.* [24] showed a significant decrease in seed weight, the number of pods/plant, the number of seeds/plant, and yield of a pea under water stress conditions. Also, water deficit caused a reduction in plant height, a number of branches/plant, siliqua/plant, seed/siliqua, 1000-seed weight, and seed yield of rapeseed [25]. Similar results were obtained by [3, 26, 27].

Table 1: Effect of different levels of ASM in combination with different levels of K on growth and oil production of *Oenothera biennis* in the 1st season

Treatment	Plant height (cm)	Number of branches	Number of capsules	Seed yield (g/plant)	Straw DW (g/plant)	Root DW (g/plant)	Plant DW (g)	Oil %	Oil yield (ml/plant)
40 ASM	64.4±0.52d*	2.23±0.15d	30.2±2.64c	2.02±0.10c	4.08±0.05c	0.67±0.02c	6.77±0.10e	24.8±0.17a-c	0.5±0.02c
60 ASM	67.2±3.03cd	3.07±0.03cd	35.9±2.60bc	2.58±0.30bc	4.48±0.11bc	0.71±0.0.04c	7.78±0.34de	24.7±0.18a-c	0.64±0.07bc
80 ASM	66.7±2.43d	3.83±0.09b-d	36.9±2.90bc	3.17±0.17ab	4.77±0.07ab	1.5±0.0.08b	9.44±0.28bc	24.5±0.09bc	0.77±0.04ab
40 ASM+K1	75.6±1.71bc	5.0±0.42a-c	31.4±3.27bc	2.4±0.15bc	4.21±0.08c	0.7±0.0.03c	7.3±0.10de	25±0.26ab	0.6±003bc
60 ASM+K1	79±0.11ab	5.73±0.18ab	41.3±1.05b	2.78±0.17a-c	4.54±0.09a-c	0.71±0.0.04c	8.04±0.25d	24.3±0.06bc	0.68±0.04a-c
80 ASM+K1	82.9±1.98ab	6.17±0.51ab	53.6±1.34a	3.17±0.22ab	4.92±0.03ab	1.65±0.0.07b	9.74±0.20ab	24.2±0.09c	0.76±0.05ab
40 ASM+K2	79.9±0.40ab	6.17±0.82ab	35.7±2.13bc	2.3±0.15bc	4.58±0.33a-c	0.72±0.0.02c	7.57±0.13de	25.2±0.13a	0.58±0.04bc
60 ASM+K2	83.8±0.94ab	6.95±0.90a	41.1±0.98b	2.95±0.05a-c	4.57±0.01a-c	0.83±0.03c	8.36±0.06cd	24.4±0.10bc	0.72±0.02a-c
80 ASM+K2	86.7±2.03a	6.47±0.58a	62.4±1.36a	3.63±0.32a	5.04±0.14a	1.96±0.03a	10.6±0.43a	24.4±0.12bc	0.89±0.08a

*Numbers accompanied by different letters are significantly different at $p \leq 0.05$ by Tukey's HSD test

The reduction in growth parameters induced by water stress may be due to a reduction in photosynthesis, stomatal and mesophyll conductance and reduction in the absorption of nutrient elements [28, 29]. Water stress causes deceleration of cell enlargement and thus reduces stem length by inhibiting internodal elongation and also reduces the tillering capacity of plants [30]. It is also clear that root dry weight/plant dry weight ratio (root/shoot ratio) decreased with increasing water deficit (Tables 1 and 2), which may attribute to the adverse effects of water stress on roots due to inhibition in root elongation, increased suberization and/or increased loss of fine roots. Under these conditions, the balance between water extraction capacity and transpiring leaf area is disturbed [31, 32]. On the other hand, the pronounced effect of increased irrigation on growth may be attributed to the availability of sufficient moisture throughout the root system [33].

As shown in Tables (1and 2), K application either at 0.4 or 0.8 g/pot levels significantly increased plant height, the number of branches, the number of capsules/plant compared to plants with no K application. Application of K at only (0.8 g/pot) led to a significant increase in dry weights of both root and straw as well as the whole plant in the two seasons when compared to unfertilized treatment. The maximum values of these parameters were observed from plants fertilized with K (0.8 g/pot). On the other hand, K application had no pronounced effect on seed yield, oil %, and oil yield as well as root dry weight/plant dry weight ratio (root/shoot ratio). The positive effect of K application on growth parameters was previously observed in mungbean [34] and *Salvia miltiorrhiza* [35]. The increase in plant height can be attributed to the fact that K enhances plant vigour and strengthens the stalk [36]. Also, K application might increase the availability of other nutrients as well as the photosynthetic activity, and transportation of photosynthesis from source to sink could be the main reason for better plant growth, a number of branches/plant and the number of seed/pod [37, 38]. The highest seed yield can be attributed to a number of pod/plant and a number of seed/pod.

Table 2: Effect of different levels of ASM in combination with different levels of K on growth and oil production of *Oenothera biennis* in the 2nd season

Treatment	Plant height (cm)	Number of branches	Number of capsules	Seed yield (g/plant)	Straw DW (g/plant)	Root DW (g/plant)	Plant DW (g)	Oil %	Oil yield (ml/plant)
40 ASM	66.2±1.38c*	2.2±0.20d	29.7±2.57cd	2.18±0.18c	3.93±0.25c	0.66±0.04d	6.77±0.31e	25±0.03a	0.55±0.05b
60 ASM	70.0±1.33bc	2.95±0.33cd	33.9±1.87b-d	2.4±0.20bc	4.63±0.23a-c	0.79±0.02cd	7.82±0.41de	25.1±0.15a	0.6±0.05b
80 ASM	69.5±3.48bc	4.23±0.24bc	41.5±2.78bc	3.43±0.30ab	4.88±0.10ab	1.4±0.09b	9.71±0.23a-c	24.4±0.09a	0.84±0.07ab
40 ASM+K1	78.1±1.94ab	4.44±0.24bc	31.3±1.02d	2.38±0.23bc	3.95±0.25bc	0.68±0.03cd	7.01±0.48de	25.1±0.09a	0.6±0.06b
60 ASM+K1	80.4±0.70a	5.3±0.13ab	40±1.79b-d	2.75±0.16a-c	4.48±0.26a-c	0.77±0.01cd	8±0.12c-e	25±0.56a	0.69±0.04ab
80 ASM+K1	82.5±2.31a	6.75±0.42a	57.4±2.37a	3.32±0.44a-c	4.99±0.05a	1.56±0.06b	9.86±0.54ab	24.2±0.09a	0.8±0.11ab
40 ASM+K2	79.5±1.66a	5.9±0.25ab	34±1.52b-d	2.29±0.12bc	4.61±0.19a-c	0.7±0.01cd	7.6±0.30de	24.8±0.23a	0.57±0.03b
60 ASM+K2	83.0±0.79a	6.53±0.48a	43.1±2.79b	3±0.29a-c	4.91±0.16a	0.9±0.03c	8.8±0.43b-d	24.5±0.07a	0.73±0.07ab
80 ASM+K2	83.0±0.76a	6.75±0.73a	65±4.05a	3.83±0.17a	5.23±0.09a	2.01±0.07a	11.1±0.25a	24.5±0.07a	0.94±0.04a

*Numbers accompanied by different letters are significantly different at $p \leq 0.05$ by Tukey's HSD test

The interaction between irrigation treatments and K fertilizer resulted in a significant increment of plant height, number of branches, number of capsules/plant, root dry weight/plant dry weight ratio (root/shoot ratio) and dry weights of both root, straw as well as a whole plant for both seasons. The maximum values were recorded from the combination of irrigation at 80 % ASM and spraying with K (0.8 g/pot) in the two seasons (Tables 1, 2), while the minimum values resulted from the treatment of irrigation at 40 % ASM and unfertilized treatment. This is in agreement with [39] who concluded that water stress reduced plant height, the number of branches, stem diameter, the number of pods, the number of seeds/pod, the number of seeds/plant, seed weight, and seed yield while the application of K restored all these parameters. Similar results have shown that the application of K fertilizer mitigates the adverse effects of drought on plant growth [6, 40, 41]. The action impacts various physiological processes such as photosynthesis, respiration, translocation of and absorption of nutrients. It is a major element that plays an important role in protein synthesis and osmotic adjustment and ultimately increasing plant resistance to drought stress [4]. Moreover, K improves the water relations in water-stressed plants by decreasing osmotic potential, thus maintaining the cell turgor that is required for the normal function of the cell [42, 43]. Therefore, maintenance of high cytoplasmic levels of K is essential for the survival of plants in stress environment [44].

Seed oil content and fatty acid profile

The oil % of evening primrose seeds was from 24.2 to 25.1 % in all treatments (Tables 1and 2), which is within the range (20-30 %) previously reported for seeds [13, 45, 46]. Hudson [47] reported that evening primrose seeds contain 24 % oil with 7 % to 14 % gamma-linolenic acid of the fatty acid components.

Oil % significantly responded to irrigation water treatments in the two seasons (table 1 and 2). Increasing applied water quantity significantly decreased essential oil percentage to reach the highest value in plants irrigated with 40 % ASM. On the other hand, oil yield (mg/plant) was significantly higher in plants received 80 % ASM than plants received 40 % ASM (Tables 1 and 2). Previous studies on other oil plants showed that the increment in oil yield with the increase in moisture stress was largely due to the positive effect of moisture stress on seed yield [48]. On the other hand, water stress caused a decrease in oil content and unsaturated fatty acids of sunflower oil [3]. This emphasizes the idea that lipids, one of the major components of the membrane, are likely to be affected by water stress. Some reports have indicated that water stress decrease oil yield in some plants, such as sunflower [49]; rapeseed [25]; sesame [50]; and milk thistle seeds [51]. However, other reports mentioned an increase in oil % with drought stress in soybean [52] and peanut [53], which may be a response to cope with a challenging environmental constraint.

Water stress affects not only the oil yield but also the lipid composition and profile in plants. However, the results are often contradictory. For example, Wilson *et al.* [54] and Pham-Thi *et al.* [55] observed that water deficit caused a significant decline in the oil as well as changes in oleic and linoleic acid contents during water stress in cotton. This decline might be due to an inhibition in.

Fatty acids desaturation or their biosynthesis [56]. A decline in the relative degree of acyl unsaturation (i.e. FA-unsaturation) in phospholipids and glycolipids could be another cause for the reduction in fatty acid content [54]. A study on two sesame cultivars showed that oleic acid content decreased with the increase in water deficit treatments, but linoleic acid % was affected in only one cultivar [57]. On the contrary in peanut, drought slightly increased oleic acid and reduced linoleic acid in oil [53]. In the current study (table 3), we found that the percentage of C16:0, C18:1n9 and C22:0 acids were increased with increasing water stress, while a reverse response was observed in C18:0, C18:2n6, C20:0, C18:3n6 and C20:1n9 acids, where water stress led to a decrease in these percentages. This clearly indicates that each compound is responding differently to water stress, and this may be due to the differential effect of water stress on the enzymatic machinery for a particular pathway that lead to the synthesis of this particular fatty acid.

Table 3: Effect of water stress and/or potassium fertilizer on the % of *Oenothera biennis* fatty acids profile in the second season

Treatment	C16:0 Palmitic acid	C1 8:0 Stearic acid	C18:1n9 Oleic acid	C18:2n6 Linoleic acid	C20:0 Arachidic acid	C18:3n6 γ-Linolenic acid	C20:1n9 Gondoic acid	C22:0 Behenic acid
40 ASM	6.77	3.11	8.40	70.60	0.52	9.78	0.59	0.23
60 ASM	6.43	2.87	8.02	71.72	0.42	9.87	0.53	0.15
80 ASM	5.99	3.49	8.33	70.80	0.55	9.89	0.84	0.11
40 ASM+K1	6.48	2.77	8.25	71.58	0.41	9.78	0.48	0.25
60 ASM+K1	6.29	2.96	8.33	71.51	0.42	9.88	0.41	0.20
80 ASM+K1	6.41	2.77	8.23	71.43	0.40	9.86	0.70	0.20
40 ASM+K2	6.33	2.77	8.22	71.32	0.42	9.89	0.68	0.17
60 ASM+K2	6.22	3.22	8.11	71.55	0.42	9.88	0.49	0.11
80 ASM+K2	6.80	2.88	8.23	71.60	0.46	9.42	0.51	0.10

Generally, application of K did not affect the accumulation of oil (% or yield) in both seasons (Tables, 1 and 2). These results are in contrast with other reports, which showed an improvement in the oil % and yield of various plants, such as sunflower [58], cotton [59], safflower [60], soybean [61], rapeseed [25] and *Jatropha curcas* [62] due to K application. On the other hand, some reports showed no positive effects of K on oil % [60, 63, 64]. Furthermore, Khan *et al.* [65] observed the significant suppressive effect on oil % of canola by different levels of K, and the maximum oil contents were found when no fertilizer was applied. In the current study, K application attenuated oil composition, where it led to a slight increase in C18:2n6 and C20:0 acid, while decreased the percentages of C16:0, C18:1n9, C22:0 acids C18:0, C18:3n6 and C20:1n9 acids, which indicates that K application influences the chemical composition of oil in *Oenothera* plants. The differential response of oil components to K application has been highlighted in the literature. For example, foliar and soil K application resulted in an increase in palmitic acid in soybean oil [66]. Foliar treatment increased linoleic acid (C18:2) while decreasing linolenic acid (C18:3) as well as oleic acid (C18:1). Soil application, however, increased linolenic acid only. In contrast, other authors have reported an increase in oleic acid by K fertilizers [67]. The inconsistency of results may be due to environmental conditions (especially, drought, heat, and soil conditions, greenhouse vs. field experiment), and genotype.

The interaction between irrigation water quantity and K significantly affected oil % (Tables 1 and 2). It also shows that the highest oil % occurred in plants irrigated with 40 % ASM plus K application (0.8 g/pot), in the first season, while 40 % ASM plus K application (0.4 g/pot) in the second season. The lowest percentage of essential oil was from plants that received 80 % irrigation treatment plus K application (0.4 g/pot) in the two seasons. Regarding the essential oil yield (mg/plant), an opposite trend was obtained, where plants received 80 % ASM plus K application (0.8 g/pot) showed the highest oil production, while plants received 40 % ASM plus K application (0.8 g/pot) showed the least oil production. Previous studies have shown that increasing irrigation levels caused a decrease in oil content, but the application of K fertilizer significantly increased oil content [68].

Interaction treatments between water levels and K fertilizer led to variable differences in fatty acid percentages. Potassium rates plus 60 % ASM increased C18:0 and C18:1n9 acids while K application with both of 60 % ASM and 40 % ASM increased C18:2n6 and C20:0 acids. The C22:0 acid increased under the interaction of all treatments of irrigation levels with (0.4 g/pot) dose of K. However, C16:0 acid increased as a result of 80 % ASM treatment with the different K rates. While C20:1n9 acid increased with K (0.8 g/pot) plus water level (40 % ASM) and C20:0 acid was not positively affected by study treatments.

CONCLUSION

Increasing irrigation levels increased the plant height, the number of branches, the number of capsules/plant and dry weights of the whole plant, root and straw of *Oenothera biennis* and the optimum irrigation level for the highest yields of these variables was 80 % ASM. Whereas, oil % decreased with increasing irrigation levels and the optimum irrigation level for the highest oil % was 40 % ASM. However, for the oil yield from plants that received 80 % ASM produced more oil yield than plants received 60 % or 40 % ASM. Application of potassium counteracted the adverse effects of water stress. Potassium fertilizer increased plant height, number of branches, number of capsules/plant and dry weights of whole plant, root and straw of *Oenothera biennis* and oil production not only under well-watered conditions (80 % ASM) but also under moderate-watered conditions (60 % ASM) and under water deficit conditions (40 % ASM). Supplying plants with a water level at 80 % ASM plus K gave the best result for plant height, the number of branches, the number of capsules/plant and dry weights of whole plant, root and straw and oil production. It can be concluded that application of potassium could be a practical approach for enhancing the oil accumulation in *Oenothera biennis*. The current study provided important information about the qualitative and quantitative changes in the fatty acids profile of *Oenothera biennis* in relation to potassium application under water stress conditions.

CONFLICT OF INTERESTS

Declared none

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