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# Effects of Different Nitrogen Doses and Row Spacing Applications on Yield and Quality of *Oenothera biennis* L. Grown in Irrigated Lowland and Unirrigated Dryland Conditions

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**Abstract:** Common evening primrose (*Oenothera biennis* L., Onagraceae) is a biennial herbaceous forb. It is commercially cultivated in over 15 countries for its seed oil, which contains the essential fatty acids, linoleic and gamma-linolenic acid. The present study was carried out to determine the effects of different nitrogen doses (0, 60, 120 and 180 kg ha$^{-1}$) and row spacing applications (20, 40 and 60 cm) on yield and quality of *Oenothera biennis* L. grown in irrigated lowland and unirrigated dryland in the Çukurova conditions region in 2000 and 2001. The field trials were arranged in split-split-plot design with 3 replicates. Some plant and technological traits of evening primrose such as plant height, the number of branches, the number of capsules in the main branch, biological and seed yields, seed crude oil content, seed oil linoleic and gamma-linolenic acid contents were studied. The biological and seed yields of *Oenothera biennis* L. varied with different growing areas, and the highest values were obtained under irrigated lowland conditions in both experimental years. For the highest yield and quality, the optimum applications were 120 kg ha$^{-1}$ nitrogen and 40 cm row spacing. The seed yields changed between 750 and 7617 kg ha$^{-1}$ according to different agricultural techniques. Because of the higher temperature during the vegetation period in the Çukurova region, the content of γ-linolenic acid of the seed oil was lower than the normal ranges reported, and varied between 3.04% and 5.98%. Furthermore, the higher doses of nitrogen fertilization affected the g-linolenic acid content negatively.

Key Words: *Oenothera biennis* L., evening primrose, nitrogen, row spacing, seed yield, gamma-linolenic acid

## Sulanan Taban ve Sulanmayan Kıraç Arazi Koşullarında Yetiştirilen *Oenothera biennis* L.'nin Verimi ve Kalitesi Üzerine Farklı Azot Dozları ve Sıra Arası Uygulamalarının Etkisi

**Özet:** Gece safası (*Oenothera biennis* L., Onagraceae) iki yıllık otsu bir bitkidir. Tohum yağının bileşimindeki linoleic ve gamma-linolenic asit gibi doymamış yağ asitlerden dolayı günümüzde yaklaşık olarak 15 ülkede bitkinin ticari anlamda tarımı yapılmaktadır. Bu çalışma, 2000 ve 2001 yıllarında Çukurova bölgesi sulanan taban ve sulanmayan kıraç arazi koşullarında *Oenothera biennis* L.'nin verim ve kalitesi üzerine farklı azot dozları ve bitki sıklıklarının etkisini belirlemek için yapılmıştır. Tarla denemeleri bölünen bölünmüş parseller deneme desenine göre üç tekrarlamalı olarak düzenlenmiş olup, yetiştirme ortamları ana parsellere, azot dozları (0, 60, 120 ve 180 kg ha$^{-1}$) alt parsellere ve bitki sıklıkları (20, 40 ve 60 cm) ise minik parsellere yerleştirilmiştir. Bu çalışmada, gece safası bitkisinin bitki boyu, dal sayısı, ana dal kapsül sayısı, biyolojik ve tohum verimleri, tohum sabit yağ oranı ile tohum sabit yağı linoleik ve gama-linolenik asit oranları gibi bazı bitkisel ve teknolojik özellikleri ele alınmıştır. Gece safası (*Oenothera biennis* L.)'nın biyolojik ve tohum verimleri farklı yetiştirme ortamlarına göre değişiklik göstermiş ve her iki deneme yılında da en yüksek verimler sulanan taban arazi koşullarından elde edilmiştir. Çalışma sonunda, gece safası bitkisinde yüksek verim ve kalite açısından optimum azot dozunun 120 kg ha$^{-1}$ ve sıra arası mesafenin ise 40 cm olduğu belirlenmiştir. Farklı tarımsal uygulamalara göre gece safası tohum verimi 750 ile 7616 kg ha$^{-1}$ arasında değişim göstermiştir. Çukurova bölgesinde vejetasyon dönemindeki yüksek sıcaklıklardan ötürü tohum yağındaki gamma-linolenic asit oranı normal değerlerin altında kalmış ve % 3.04 – 5.98 arasında değişmiştir. Yüksek azot dozları da γ-linolenik asit oranını olumsuz yönde etkilemiştir.

Anahtar Sözcükler: *Oenothera biennis* L., gece safası, Azot, sıra arası, tohum verimi, gamma-linolenic asit

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## Introduction

Evening primrose (*Oenothera biennis* L.) is native to North America. It is a tall plant (around 1-2 m) with handsome, bright yellow flowers. It was imported from North America to Europe nearly 200 years ago, and can now be found in sandy soils and on railway embankments throughout Europe. The plant got its name from the fact that the flowers first open in the evening, and then remain wide open during the next day. Depending on different agricultural applications and growing conditions, seed yields show in a wide range (e.g., 286-3750 kg $ha^{-1}$) (Uzzan, 1988; Brandle et al., 1993; Graf et al., 1997; Adam et al., 1998; Deng et al., 2001). The seeds of evening primrose contain large quantities of fatty oil (19.3%-29.4%) with mainly 70% linolenic acid and around 10% gamma-linolenic acid (GLA). These omega-6 fatty acids are now becoming increasingly popular as oral and topical remedies for neurodermatitis. Their mechanism of action is based on the concept that the disease is caused by an underlying metabolic disorder of long-chained essential fatty acids that are, in turn, precursors of the highly active prostaglandins E1 and E2. Evening primrose oil has been used in several studies to test its use for breast pain, PMS, eczema, cirrhosis, rheumatoid arthritis, menopause etc. (Yaniv and Perl, 1987; Weiss and Fintelmann, 2000; Deng et al., 2001).

Different growing conditions and agricultural applications affect the yield and quality of the plants. Although lowland conditions have suitable moisture and organic material for plant development, dryland conditions are commonly not optimum for plant development. Different row spacing applications affect plant development. In the wider spacing applications, plants have more nutrition, water and air, but in the narrower ones, they have restricted conditions for development. In unirrigated areas, moisture is one of the most important factors affecting yield and yield components. If there is sufficient moisture in the growing area, the effectiveness of nitrogen for plants will increase, and applying nitrogen at high doses will increase seed yield (Akten and Akkaya, 1986).

Evening primrose oil has been used extensively in the additive and herbal medicine industries in recent times. Evening primrose is commercially cultivated in over 15 countries for its oil (Kemper, 1999). Demand for these products in Turkey has been supplied from other countries. The main purpose of the present study was to determine the optimum growing conditions, cultivation techniques and N fertilizer requirements for evening primrose (*Oenothera biennis* L.) in irrigated lowland and unirrigated dryland conditions.

## Materials and Methods

This study was carried out to determine the effects of different nitrogen doses and plant densities on the yield and quality of *Oenothera biennis* L. grown in the experimental fields with irrigated lowland and unirrigated dryland conditions at Çukurova University, Agricultural Faculty, Field Crops Department, in 2000 and 2001.

In this region during the vegetation period, the average climate values were 25.4 °C and 195.3 mm rainfall for 2000, and 25.2 °C and 204.4 mm rainfall for 2001. In 2001, more than half of the total rainfall (130.4 mm) fell in May in 2001, with 68.1 mm in 2000. The soil characteristics of the experimental areas are given in Tables 1 and 2.

Field trials were arranged in split-split-plot design at 2 different locations with 3 replicates. The locations

Table 1. Some physical and chemical soil properties of the experimental area in lowland fields.

| Years | Depth (cm) | Texture | pH | Salt (%) | $P_2O_5$ (kg $ha^{-1}$) | Total N (%) | Lime (%) | Cu (mg $kg^{-1}$) | Mn (mg $kg^{-1}$) | Fe (mg $kg^{-1}$) | Zn (mg $kg^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 0-30 | Clay-loam | 7.50 | 0.040 | 85.1 | 0. 13 | 24 | 0.89 | 7.57 | 5.23 | 1.07 |
| | 30-60 | Clay-loam | 7.58 | 0.030 | 55.3 | 0. 15 | 27 | - | - | - | - |
| 2001 | 0-30 | Clay-loam | 7.52 | 0.050 | 96.2 | 0. 10 | 26 | 1.17 | 8.60 | 4.37 | 0.93 |
| | 30-60 | Clay-loam | 7.60 | 0.040 | 64.7 | 0. 12 | 28 | - | - | - | - |

Table 2. Some physical and chemical soil properties of the experimental area in dryland fields.

| Years | Depth (cm) | Texture | pH | Salt (%) | $P_2O_5$ (kg ha$^{-1}$) | Total N (%) | Lime (%) | Cu (mg kg$^{-1}$) | Mn (mg kg$^{-1}$) | Fe (mg kg$^{-1}$) | Zn (mg kg$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 0-30 | Clay | 7.46 | 0.060 | 83.7 | 0. 16 | 22 | 1.07 | 8.46 | 4.89 | 1.18 |
| | 30-60 | Clay | 7.50 | 0.070 | 58.4 | 0. 12 | 25 | - | - | - | - |
| 2001 | 0-30 | Clay | 7.51 | 0.070 | 91.3 | 0. 14 | 22 | 1.23 | 9.47 | 4.63 | 0.97 |
| | 30-60 | Clay | 7.50 | 0.072 | 67.6 | 0. 13 | 24 | - | - | - | - |

(lowland and dryland) were the main plots; the different nitrogen doses (0, 60, 120 and 180 kg ha$^{-1}$) were the subplots and the small plots were row spacing applications (20, 40 and 60 cm).

The seeds, obtained from Germany (Institut für Pflanzenbau und Pflanzenzüchtung, Justus Liebig Universitaet Giessen, Germany), were sown in seedbeds in the greenhouse in January to obtain seedlings. The seedlings were transplanted to the experimental area at the end of March. In both the lowland and dryland trials, after transplanting the seedlings were irrigated until they adapted to their surroundings. The lowland fields were irrigated at monthly intervals when 75% of the capsules had ripened. They were harvested at the beginning of September in 2000 and at the end of August in 2001. The plants were dried under the sun in the field for 1 week, and then they were threshed. Afterwards, laboratory analyses were made in the seeds. Before harvesting, some yield components such as plant height, the number of branches and the number of capsules in the main branch were measured in the plots.

The crude oil analyses were performed with a Raney Oilseed Crusher. Gas chromatography (GC) analyses of essential fatty acids were carried out using a Hewlett Packard 6890 series gas chromatograph [split/splitless injection system equipped with a capillary column (30 m x 0.32 mm i.d.), initial temp.: 170 °C for 3 min, final temp.: 210 °C for 10 min, carrier gas: nitrogen] after methyl esterification by $BF_3.CH_3OH$. Linoleic (18:2, n-6) and gamma-linolenic (18:3, n-6) acids were determined in the seed oil (Christie, 1995).

The statistical analyses were performed according to split-split-plot design by the computer statistical program MSTATC. The differences among the means were compared using LSD (5%).

## Results and Discussion

### Plant Height

There were no significant differences between the years, varying nitrogen doses and row spacing applications regarding the plant height values of evening primrose (Table 3). Plant height was significantly changed by the different locations. As expected, the highest plant height values were obtained from the irrigated lowland conditions in both years, because these conditions were favorable in terms of nutrition and water supply for plant development.

In view of the years, different locations, varying nitrogen doses and row spacing applications, the highest plant height values were obtained in 2001 for lowland conditions, at 120 kg ha$^{-1}$ nitrogen doses and 20 cm row spacing. Because of very high rainfall in the first development stage in May 2001 (130.4 mm), higher plant heights were obtained in the first year. In 2000, there was 68.1 mm rainfall during the same time. The plants were also in the pre-flowering period in May. The plant height results obtained from the present study were in agreement with those reported by other researchers. In our studies, the plant height values ranged from 90.9 to 173.7 cm according to different cultural applications, while this variation was between 90 cm and 175 cm in other studies (Reiner et al., 1989; Deng et al., 2001).

### The Number of Branches

The number of the branches of evening primrose was statistically changed by different locations in the experimental years (Table 4). The highest number of branches was obtained from lowland conditions in both years. Different row spacing applications affected the number of branches of evening primrose, and the highest values occurred in the 60 cm row spacing application in 2000 and 2001.

Table 3. Average values of plant height (cm).

| Years | Nitrogen (kg ha$^{-1}$) | Location and Row Spacing (cm) | | | | | | Nitrogen Means |
|---|---|---|---|---|---|---|---|---|
| | | Lowland | | | Dryland | | | |
| | | 20 | 40 | 60 | 20 | 40 | 60 | |
| 2000 | 0 | 142.4 | 137.7 | 140.8 | 96.6 | 95.3 | 99.0 | 118.6 |
| | 60 | 146.2 | 145.5 | 142.3 | 99.4 | 94.2 | 91.2 | 119.8 |
| | 120 | 142.3 | 147.3 | 139.5 | 103.6 | 98.5 | 90.9 | 120.3 |
| | 180 | 138.9 | 145.3 | 138.9 | 94.1 | 99.3 | 96.7 | 118.9 |
| | Location Means | 142.3 a | | | 96.6 b | | | |
| | Space Means | 120.4 | | 120.4 | | 117.4 | | |
| LSD (5%): Location: 15.13 | | | | | | | | |
| 2001 | 0 | 165.7 | 146.8 | 159.3 | 97.8 | 105.3 | 98.0 | 128.8 |
| | 60 | 170.7 | 164.4 | 163.9 | 116.7 | 104.9 | 106.8 | 137.9 |
| | 120 | 173.5 | 172.4 | 170.5 | 112.7 | 105.6 | 101.7 | 139.4 |
| | 180 | 173.7 | 146.4 | 170.5 | 100.1 | 110.1 | 102.3 | 133.9 |
| | Location Means | 164.8 a | | | 105.2 b | | | |
| | Space Means | 138.9 | | 132.0 | | 134.1 | | |
| LSD (5%): Location: 16.01 | | | | | | | | |

There were no statistical differences between means with the same letters.

Table 4. Average values of the number of branches (branch plant$^{-1}$).

| Years | Nitrogen (kg ha$^{-1}$) | Location and Row Spacing (cm) | | | | | | Nitrogen Means |
|---|---|---|---|---|---|---|---|---|
| | | Lowland | | | Dryland | | | |
| | | 20 | 40 | 60 | 20 | 40 | 60 | |
| 2000 | 0 | 11.7 | 13.9 | 18.4 | 7.7 | 6.4 | 9.2 | 11.2 |
| | 60 | 10.1 | 12.7 | 15.0 | 7.5 | 11.1 | 10.5 | 11.1 |
| | 120 | 11.3 | 14.7 | 17.8 | 5.0 | 9.3 | 10.8 | 11.5 |
| | 180 | 16.9 | 15.5 | 17.3 | 6.7 | 10.0 | 10.6 | 12.8 |
| | Location Means | 14.6 a | | | 8.7 b | | | |
| | Space Means | 9.6 c | | 11.7 b | | 13.7 a | | |
| LSD (5%): Location: 5.287; Space: 1.420 | | | | | | | | |
| 2001 | 0 | 15.9 | 20.47 | 24.8 | 16.9 | 20.6 | 16.7 | 19.3 b |
| | 60 | 19.6 | 28.6 | 25.2 | 19.3 | 17.9 | 17.5 | 21.4 ab |
| | 120 | 24.3 | 34.5 | 32.8 | 19.0 | 18.0 | 18.5 | 24.5 a |
| | 180 | 27.9 | 29.9 | 37.3 | 18.9 | 13.4 | 17.5 | 24.1 a |
| | Location Means | 26.8 a | | | 17.9 b | | | |
| | Space Means | 20.2 b | | 22.9 ab | | 23.8 a | | |
| LSD (5%): Location: 4.428; Nitrogen: 3.526; Space: 3.054 | | | | | | | | |

There were no statistical differences between means with the same letters.

Irrigated lowland fields had optimum growing conditions, and the wider row spacing applications permitted plants to produce more branches. Although there were no significant differences among the varying nitrogen doses in 2000, increasing nitrogen doses significantly affected the number of branches per plant in 2001.

The interaction between locations and nitrogen in the experimental years for the number of branches of evening primrose was statistically significant. The highest values were obtained in the lowland conditions with 120 and 180 kg $ha^{-1}$ and in dryland conditions with 60 and 120 kg $ha^{-1}$ nitrogen applications in 2000 and 2001 (Figure 1). In the lowland growing conditions, where soil moisture was optimum, fertilizers can be used efficiently by plants. Likewise, in this study where the moisture was optimum in the lowland fields a large number of branches was produced at the higher fertilizer doses.

According to the years, locations, nitrogen doses and plant densities, the number of branches of evening primrose varied from 5.0 to 37.3 branches per plant. The highest numbers of branches were obtained in the 60 cm row spacing with 120 and 180 kg $ha^{-1}$ nitrogen doses in the lowland conditions in both years. The wider growing area for plants promotes the production of more branches.

In the present study, the highest numbers of branches of evening primrose were obtained from the wider row spacing applications and the higher nitrogen doses under irrigated lowland conditions in both years. The number of branches depends mainly on the soil fertility, growing conditions and agronomical applications. In the optimum growing conditions plants produce more branches. Our studies confirm those by Reiner et al. (1989), who also reported that 17.5 plant $m^2$ row spacing resulted in a higher number of branches in evening primrose.

### The Number of Capsules

In both experimental years, the highest number of capsules per main branch was obtained in the lowland conditions (Table 5). Different row spacing applications did not affect the number of capsules per main branch statistically. Varying nitrogen doses had different effects on the number of capsules per main branch in each year. Although the highest values were obtained from the control plots in 2000, in the second year the highest value was obtained with the 120 kg N $ha^{-1}$ application. In 2001, there was a higher amount of rainfall than in 2000. Thus, the higher nitrogen doses applied in 2001 were used more efficiently for producing more capsules.

There were differences between the experimental years in terms of the number of capsules in the main

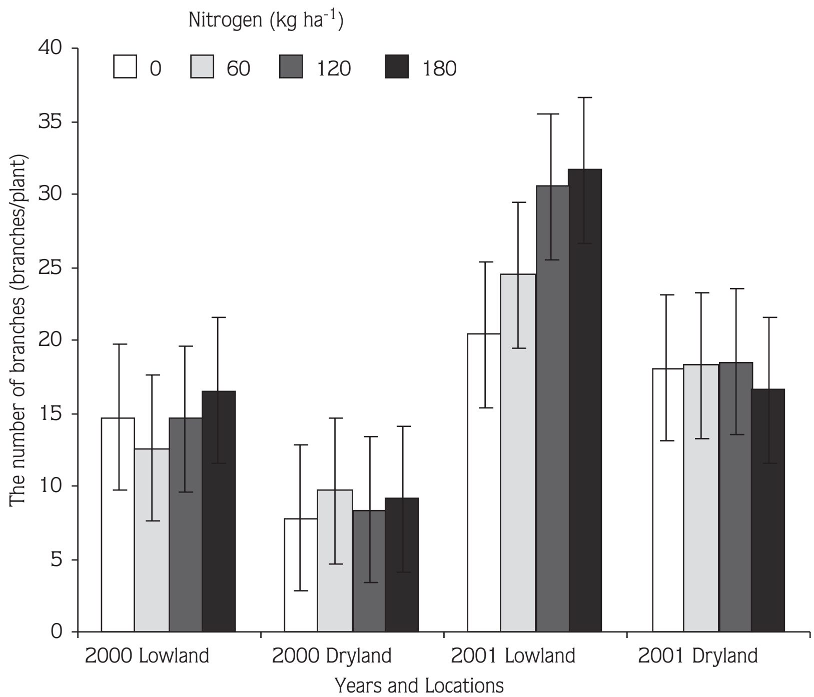


Figure 1. The number of branches values at different locations and nitrogen applications.

Table 5. Average values of the number of capsules in main branch (capsule main branch$^{-1}$).

| Years | Nitrogen (kg ha$^{-1}$) | Location and Row Spacing (cm) | | | | | | Nitrogen Means |
|---|---|---|---|---|---|---|---|---|
| | | Lowland | | | Dryland | | | |
| | | 20 | 40 | 60 | 20 | 40 | 60 | |
| 2000 | 0 | 97.7 | 79.8 | 89.2 | 53.3 | 62.1 | 62.0 | 74.0 a |
| | 60 | 87.5 | 91.0 | 76.9 | 46.6 | 44.0 | 43.5 | 64.9 b |
| | 120 | 80.0 | 77.7 | 74.5 | 60.6 | 51.7 | 50.1 | 65.8 b |
| | 180 | 71.9 | 86.3 | 87.7 | 42.3 | 54.8 | 48.5 | 65.3 b |
| | Location Means | | 83.4 a | | | 51.6 b | | |
| | Space Means | 67.5 | | 68.4 | | 66.6 | | |
| LSD (5%): Location: 2.354; Nitrogen: 7.453 | | | | | | | | |
| 2001 | 0 | 105.7 | 75.3 | 112.8 | 44.4 | 59.9 | 42.8 | 73.5 |
| | 60 | 108.9 | 79.3 | 102.5 | 62.3 | 52.7 | 55.5 | 76.9 |
| | 120 | 93.3 | 109.5 | 129.3 | 66.7 | 58.3 | 50.9 | 84.7 |
| | 180 | 114.1 | 105.6 | 102.9 | 54.7 | 53.7 | 47.9 | 79.8 |
| | Location Means | | 103.3 a | | | 54.1 b | | |
| | Space Means | 81.3 | | 74.3 | | 80.6 | | |
| LSD (5%): Location: 9.008 | | | | | | | | |

There were no statistical differences between means with the same letters.

branch, and higher values were recorded in the second experimental year. In addition, the wider row spacing and the higher nitrogen applications gave a higher number of capsules per main branches under the lowland conditions. The number of capsules per main branch varied from 42.3 to 129.3 capsules per main branch.

### Biological Yield

Biological yields of the plants were affected by increasing nitrogen doses in different growing conditions in both experimental years (Table 6). Higher biological yields were obtained from the second experimental year in all the applications. Most of the annual rainfall fell in the first development stage of the seedlings in 2001. Consequently, plants developed well and produced more flowers and fruits. There were significant differences between the different growing conditions for biological yields. The highest biological yields were obtained under lowland conditions in both years.

There were no significant differences among the varying row spacing applications for biological yield of the plants in both years. The highest biological yields were obtained from the wider row spacing applications. Moreover, the highest biological yields were obtained at the higher nitrogen doses in the experimental years. The higher nitrogen doses improved plant height, branch number per plant and capsules number per main branches, and thus increased biological yields. As a result, biological yields of evening primrose varied from 7215 to 45,225 kg ha$^{-1}$ with varying agricultural applications in the 2 years.

### Seed Yield

There were no significant differences among the different nitrogen doses and varying row spacing applications in terms of the seed yield of evening primrose (Table 7). Different growing conditions significantly affected the seed yield of evening primrose. The highest seed yields were obtained under the irrigated lowland conditions in both years. In addition, there was a wide range of seed yields between the locations. Depending on the optimum growing conditions and additional irrigation during the vegetation period, higher seed yields were obtained from the lowland fields. Under unirrigated dryland conditions, weaker plants with lower yield components gave lower seed yields.

Table 6. Average values of the biological yields (kg $ha^{-1}$).

| Years | Nitrogen (kg $ha^{-1}$) | Location and Row Spacing (cm) | | | | | | Nitrogen Means |
|---|---|---|---|---|---|---|---|---|
| | | Lowland | | | Dryland | | | |
| | | 20 | 40 | 60 | 20 | 40 | 60 | |
| 2000 | 0 | 21,669 | 21,181 | 26,708 | 10,454 | 7215 | 8750 | 15,996 |
| | 60 | 27,036 | 26,183 | 21,189 | 12,049 | 11,167 | 7854 | 17,580 |
| | 120 | 25,917 | 28,360 | 25,075 | 9458 | 9537 | 8801 | 17,858 |
| | 180 | 26,867 | 24,375 | 26,053 | 9843 | 11,282 | 8438 | 17,810 |
| | Location Means | | 25,051 a | | | 9571 b | | |
| | Space Means | 17,912 | | 17,413 | | 16,609 | | |
| LSD (5%): Location: 12,290 | | | | | | | | |
| 2001 | 0 | 29,625 | 25,514 | 36,578 | 10,103 | 9861 | 10,964 | 20,441 b |
| | 60 | 39,189 | 32,325 | 34,664 | 12,433 | 12,600 | 13,436 | 24,108 a |
| | 120 | 38,631 | 42,953 | 37,214 | 12,922 | 13,539 | 11,823 | 26,180 a |
| | 180 | 41,064 | 42,041 | 45,225 | 12,639 | 12,625 | 10,919 | 27,419 a |
| | Location Means | | 37,085 a | | | 11,989 b | | |
| | Space Means | 24,576 | | 23,932 | | 25,103 | | |
| LSD (5%): Location: 13,370; Nitrogen: 3379 | | | | | | | | |

There were no statistical differences between means with the same letters.

Table 7. Average values of the seed yields (kg $ha^{-1}$).

| Years | Nitrogen (kg $ha^{-1}$) | Location and Row Spacing (cm) | | | | | | Nitrogen Means |
|---|---|---|---|---|---|---|---|---|
| | | Lowland | | | Dryland | | | |
| | | 20 | 40 | 60 | 20 | 40 | 60 | |
| 2000 | 0 | 3639 | 3489 | 4634 | 1310 | 1074 | 792 | 2490 |
| | 60 | 4428 | 3797 | 3064 | 1222 | 1097 | 750 | 2393 |
| | 120 | 3678 | 4192 | 3751 | 1250 | 1097 | 1005 | 2495 |
| | 180 | 3897 | 3361 | 4117 | 1014 | 1421 | 940 | 2458 |
| | Location Means | | 3837 a | | | 1081 b | | |
| | Space Means | 2555 | | 2441 | | 2381 | | |
| LSD (5 %): Location: 1662 | | | | | | | | |
| 2001 | 0 | 5453 | 4707 | 7000 | 1077 | 1043 | 1133 | 3402 |
| | 60 | 7037 | 5727 | 6220 | 1200 | 1153 | 1047 | 3731 |
| | 120 | 7027 | 7617 | 7023 | 1130 | 1347 | 1063 | 4201 |
| | 180 | 7283 | 7357 | 7203 | 1020 | 883 | 950 | 4116 |
| | Location Means | | 6638 a | | | 1087 b | | |
| | Space Means | 3903 | | 3729 | | 3955 | | |
| LSD (5%): Location: 2786 | | | | | | | | |

There were no statistical differences between means with the same letters.

Increasing nitrogen doses increased the seed yield and the highest seed yield was obtained from 120 kg ha$^{-1}$ application in both years. In the second year, a higher seed yield occurred at all nitrogen levels.

In the present study, seed yield of evening primrose varied over a wide range (750-7617 kg ha$^{-1}$), depending on the different cultural applications applied and growing conditions in the 2 years. The results reported in this study agree with those published elsewhere. Reiner et al. (1989) found that the seed yield of evening primrose in Turkey varied between 1800 and 2107 kg ha$^{-1}$. Deng et al. (2001) reported that the seed yield of evening primrose in China ranged between 1125 and 1530 kg ha$^{-1}$. In other studies, seed yields varied between 286 and 2000 kg ha$^{-1}$ (Uzzan, 1988; Brandle et al., 1993; Graf et al., 1997; Adam et al., 1998).

Seed Crude Oil Content

Seed crude oil content of evening primrose was significantly affected by varying nitrogen doses in 2000 and the experimental conditions applied in 2001 (Table 8). The highest seed crude oil contents were obtained under lowland conditions in both years. The highest seed crude oil contents occurred in the control plots without N application in both years. There were also no statistical differences among the first 3 nitrogen applications in terms of their effect on the seed crude oil content in 2000.

When both years were compared, higher crude oil contents were obtained in 2000. Generally the lower nitrogen doses gave the higher crude oil content values in 2000 and 2001. The results indicate a negative relationship between seed yield (Table 7) and oil contents (Table 8). The negative relationship between yield and quality parameters is well documented for a range of crop species (Özer et al., 1999; Casini et al., 2003; Yin and Vyn, 2005).

Our crude oil contents varied from 16.7% to 27.0% in both years. These values are similar to those reported previously: 19.3%-29.4% (Yaniv and Perl, 1987), 25.5%-26.8% (Reiner et al., 1989), 17.0%-25.0% (Simpson and Fieldsend, 1993), 21.5%-25.0% (Roy et al., 1994) and 23.0%-27.8% (Fieldsend and Morison, 2000).

Table 8. Average values of the seed crude oil content (%).

| Years | Nitrogen (kg ha$^{-1}$) | Location and Row Spacing (cm) | | | | | | Nitrogen Means |
|---|---|---|---|---|---|---|---|---|
| | | Lowland | | | Dryland | | | |
| | | 20 | 40 | 60 | 20 | 40 | 60 | |
| 2000 | 0 | 25.7 | 25.7 | 26.3 | 25.3 | 25.0 | 25.0 | 25.5 a |
| | 60 | 24.0 | 23.3 | 25.0 | 23.3 | 25.0 | 25.0 | 24.3 ab |
| | 120 | 25.0 | 24.3 | 26.3 | 25.3 | 26.0 | 24.7 | 25.3 a |
| | 180 | 25.0 | 22.3 | 25.7 | 23.3 | 23.0 | 23.7 | 23.8 b |
| | Location Means | | 24.9 | | | 24.6 | | |
| | Space Means | 24.6 | | 24.3 | | 25.2 | | |
| LSD (5%): Nitrogen: 1.263 | | | | | | | | |
| 2001 | 0 | 27.0 | 22.0 | 22.5 | 22.0 | 21.5 | 20.3 | 22.6 |
| | 60 | 21.7 | 24.0 | 23.3 | 20.7 | 23.2 | 22.0 | 22.5 |
| | 120 | 22.5 | 22.0 | 23.0 | 16.7 | 20.3 | 18.7 | 20.5 |
| | 180 | 24.5 | 24.0 | 25.2 | 18.0 | 16.8 | 17.2 | 20.9 |
| | Location Means | | 23.5 a | | | 19.8 b | | |
| | Space Means | 21.6 | | 21.7 | | 21.5 | | |
| LSD (5%): Location: 1.208 | | | | | | | | |

There were no statistical differences between means with the same letters.

### Seed Oil Linoleic Acid Content

In contrast to the results obtained in 2001, there were significant differences between the different growing conditions, row spacing and nitrogen applications for linoleic acid content in 2000 (Table 9). The highest linoleic acid contents were obtained under lowland conditions in 2000 and dryland conditions in 2001. Although increasing nitrogen doses had no effects on linoleic acid contents in 2000, there were, however, significant differences between the nitrogen doses. On average, the highest linoleic acid contents were observed in the control plots in 2000 and at the 120 kg $ha^{-1}$ nitrogen application in 2001.

Different row spacing applications had no statistical effects on the seed oil linoleic acid content. The highest linoleic acid contents were obtained in the 20 cm spacing application. As found with oil content, the highest linoleic acid contents were found in 2000 and negatively correlated with seed yields in 2000 and 2001. The narrower row spacing applications gave the higher linoleic acid contents in both years.

In the present study, linoleic acid contents varied between 49.2% and 73.8% under the given conditions. The variation in linoleic acid found in the present study was similar to the variation reported in the literature such as 65.2%-68.3% (Reiner et al., 1989), 61.9%-74.6% (Yaniv et al., 1989), 70.1%-72.5% (Roy et al., 1994) and 73.5%-81.9% (Deng et al., 2001). According to the experiments carried out by Reiner et al. (1989), the control plots without N application and narrower row spacing gave higher linoleic acid contents of evening primrose oil in Turkey. This was associated with the low yield of the researchers. It seems likely that linoleic acid content is affected by climatic differences between the years and thus by variation in yield.

### Seed Oil Gamma-linoleic Acid (GLA) Content

Although there were no significant differences between the different growing conditions for the GLA content of evening primrose oil in 2001, different locations, however, significantly affected GLA content in 2000 (Table 10). The highest GLA contents were obtained under dryland conditions in 2000 and under lowland conditions in 2001. Variation in N applications

Table 9. Average values of the seed oil linoleic acid content (%).

| Years | Nitrogen (kg $ha^{-1}$) | Location and Row Spacing (cm) | | | | | | Nitrogen Means |
|---|---|---|---|---|---|---|---|---|
| | | Lowland | | | Dryland | | | |
| | | 20 | 40 | 60 | 20 | 40 | 60 | |
| 2000 | 0 | 64.6 e-h | 67.7 b-f | 71.3 ab | 63.9 e-h | 65.1 d-h | 69.8 a-d | 67.1 |
| | 60 | 70.5 a-c | 73.8 a | 58.8 i | 70.4 a-c | 61.2 hi | 64.1 e-h | 66.5 |
| | 120 | 64.5 e-h | 65.9 c-h | 67.8 b-f | 68.2 b-f | 62.6 g-i | 67.0 b-g | 66.0 |
| | 180 | 64.5 e-h | 68.4 b-e | 65.2 d-h | 66.5 b-g | 65.5 c-h | 63.2 f-i | 65.5 |
| | Location Means | | 66.9 | | | 65.6 | | |
| | Space Means | 66.6 | | 66.3 | | 65.9 | | |
| LSD (5%): Location x Nitrogen x Space: 5.10 | | | | | | | | |
| 2001 | 0 | 62.3 | 56.8 | 59.3 | 57.3 | 55.7 | 53.8 | 57.5 b |
| | 60 | 60.6 | 62.0 | 62.9 | 55.4 | 49.2 | 53.1 | 57.2 b |
| | 120 | 60.5 | 57.7 | 50.7 | 71.7 | 72.8 | 65.7 | 63.2 a |
| | 180 | 54.0 | 57.7 | 58.0 | 57.0 | 66.7 | 68.5 | 61.5 a |
| | Location Means | | 58.6 b | | | 61.2 a | | |
| | Space Means | 60.7 | | 59.8 | | 59.0 | | |
| LSD (5%): Location: 1.45; Nitrogen: 2.45 | | | | | | | | |

There were no statistical differences between means with the same letters.

Table 10. Average values of the seed oil gamma-linoleic acid content (%).

| Years | Nitrogen (kg ha$^{-1}$) | Location and Row Spacing (cm) | | | | | | Nitrogen Means |
|---|---|---|---|---|---|---|---|---|
| | | Lowland | | | Dryland | | | |
| | | 20 | 40 | 60 | 20 | 40 | 60 | |
| 2000 | 0 | 4.04 | 4.13 | 3.81 | 5.39 | 4.76 | 4.01 | 4.35 b |
| | 60 | 4.09 | 3.16 | 3.94 | 4.15 | 3.70 | 4.17 | 3.87 c |
| | 120 | 5.00 | 4.57 | 4.06 | 4.72 | 4.35 | 3.87 | 4.43 b |
| | 180 | 4.63 | 4.46 | 4.94 | 5.18 | 4.19 | 5.42 | 4.80 a |
| | Location Means | | 4.23 | | | 4.49 | | |
| | Space Means | 4.65 a | | 4.16 b | | 4.28 b | | |
| LSD (5%): Nitrogen: 0.35; Space: 0.30 | | | | | | | | |
| 2001 | 0 | 4.94 c-e | 3.93 f-h | 5.13 b-d | 5.07 b-e | 4.98 b-e | 5.23 a-c | 4.89 a |
| | 60 | 5.06 b-e | 5.32 a-c | 5.35 a-c | 5.98 a | 4.30 d-g | 5.29 a-c | 5.22 a |
| | 120 | 4.73 c-f | 4.99 b-e | 5.78 ab | 3.69 g-i | 3.61 g-i | 3.04 i | 4.30 b |
| | 180 | 4.97 b-e | 4.75 c-f | 4.79 c-e | 3.40 hi | 3.64 g-i | 4.24 e-g | 4.30 b |
| | Location Means | | 4.97 a | | | 4.37 b | | |
| | Space Means | 4.73 ab | | 4.44 b | | 4.86 a | | |
| LSD (5%): Location x Nitrogen x Space: 0.83; Location: 0.11; Nitrogen: 0.34; Space: 0.30 | | | | | | | | |

There were no statistical differences between means with the same letters.

significantly affected the GLA content of evening primrose oil in the 2 experimental years. The highest GLA contents were obtained with 180 kg ha$^{-1}$ and 60 kg ha$^{-1}$ applications in 2000 and 2001, respectively. The lowest GLA contents were found with 60 kg ha$^{-1}$ in 2000 and 120-180 kg ha$^{-1}$ in 2001.

There were significant differences among the varying row spacing applications on seed oil GLA content in both years. Although the highest GLA content was determined in 20 cm row spacing application in 2000, the highest value was found with 60 cm application in 2001. However, there were no significant differences between the 20 and 60 cm row spacing applications in 2001.

GLA contents of evening primrose oil were affected by increasing nitrogen doses, and varying row spacing applications under different growing conditions. The GLA content under the given conditions was between 3.04% and 5.98% (Table 10). There are a number of soil, climatic and plant factors affecting the fatty acid composition of the plant oils. For example, high temperatures in the first vegetation period decrease the formation of unsaturated fatty acids in the oil plants. Levy et al. (2002) indicated that a high temperature regime (32/27 °C) decreases the GLA content when compared to a low temperature regime (17/12 °C), and the most sensitive stage affecting the GLA content is 30-40 days after anthesis as shown in *Oenothera lamarckiana* L. The GLA content of *Oenothera biennis* L. was much lower in Turkey (5.80%-6.90%) when compared to that in Germany (10%), assuming that temperature was a highly influential factor for forming GLA (Reiner et al., 1989). In addition, Reiner et al. (1989) reported that the highest GLA content (6.90%) of *Oenothera biennis* L. in Turkey was obtained under conditions without N application and with 17.5 plant m$^2$ row spacing. Different studies on the GLA content of evening primrose oil showed that it varied from 5.50% to 13.30% percent. In the present study, the GLA contents obtained under given conditions were rather low compared with the results given in the literature (Simpson and Fieldsend, 1993; Roy et al, 1994; Deng et al., 2001). It is possible that differences in temperature and yield between the experimental conditions were the main factors affecting the GLA content. In the present study, the plants were exposed to high temperatures at all of the development stages. Previously, Lotti et al. (1984) reported that spring sowing yielded a lower GLA concentration than in autumn in Italy. Levy et al. (2002) reported that early flowering cultivars of evening primrose could be successfully used to obtain high GLA contents in hot climate regions.

## Conclusion

Irrigated lowland conditions were optimum for plant better development, resulting in higher yield and yield components in both experimental years. The optimum nitrogen doses and row spacing applications for the highest yield and quality were 120 kg $ha^{-1}$ and 40 cm, respectively. However, increasing nitrogen doses affected the gamma-linolenic acid content of evening primrose oil negatively. Considering that high temperatures during the first flowering period affect the fatty acid composition of the evening primrose oil negatively, early flowering cultivars should be cultivated in hot climates.

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## References

Adam, L., B. Ditmann and U. Oberdoerster, 1998. Nachtkerze (*Oenothera biennis* L.) –eine alternative im Land Brandenburg. Fachtagung “ Arznei-und Gewürzpflanzen “ am 01. Und 02. Oktober 1998 in der Justus-Liebig-Universität Gießen.

Akten, Ş. and A. Akkaya. 1986. Kıraç koşullarda farklı gübre uygulamalarının bazı kışlık arpa çeşitlerinde kışa dayanıklılık ve dane verimi ile bazı verim öğelerine etkisi. Doğa Tr. Tar. Or. D., 10: 127–140.

Brandle, J.E., W.A. Court and R.C. Roy. 1993. Heritability of seed yield, oil concentration and oil quality among wild biotypes of Ontario evening primrose. Can. J. Plant Sci. 73: 1067-1070.

Casini, C., J.L. Dardanelli, M.J. Martinez, M. Balzarini, C.S. Borgogno and M. Nassetta. 2003. Oil quality and sugar content of peanuts (*Arachis hypogaea*) grown in Argentina: their relationship with climatic variables and seed yield. J. Agric. Food Chem. 51: 6309-13.

Christie, W.W. 1995. Are methyl esters of fatty acids the best choice for gas chromatographic analysis? Lipid Tech. 7: 64-66.

Deng, Y., H.M. Hua, J. Li and P. Lapinskas. 2001. Studies on cultivation and use of evening primrose (*Oenothera* spp.) in China. Econ. Bot. 55: 83-92.

Fieldsend, A.F. and J.I.L. Morison. 2000. Climatic conditions during seed growth significantly influence oil content and quality in winter and spring evening primrose crops (*Oenothera* spp.). Ind. Crops Prod. 12:137-147.

Graf, T., A. Biertumpfel and G. Wurl. 1997. Beeinflussung des Korn- und Ölertrages sowie der Qualität von Nachtkerze (*Oenothera biennis*) durch agrotechnische Maßnahmen. Drogenreport Jg. 72: 10.

Kemper, K.J., MD. MPH. 1999. The Longwood Herbal Taskforce and the Center for Holistic Pediatric Education and Research. Evening Primrose (*Oenothera biennis*). (http://www.mcp.edu/ herbal/epo/ epo.pdf .29 April 2004).

Levy, A., Z. Yaniv, E. Menagem and M. Barzilai. 2002. Genotype-Temperature Interaction for Gamma-linolenic Acid Content in Seeds of *Oenothera lamarckiana* L. Proceedings of the Workshop on Agricultural and Quality Aspects of Medicinal and Aromatic Plants. 1-7.

Lotti, G., R. Izzo, F. Bottazzi and A. Bellani. 1984. Influence dellepoca di semina sul ciclo di sviluppo della planta e sulle caretteristiche dell’’olio di *Oenothera biennis* L. Agrochimica. 28: 85-95.

Özer, H., E. Oral and Ü. Doğru. 1999. Relationships between yield and yield components on currently improved spring rapeseed cultivars. Turk. J. Agric. For. 23: 603-607.

Reiner, H., A. Ceylan and R. Marquard. 1989. Agronomic Performance of Evening Primrose (*Oenothera biennis* L.) in Turkey and Germany. Eucarpia Congress, Gottingen. 20: 5.

Roy, R.C., P.H. White, A.F. More, J.G. Hendel, R. Pocs and W.A. Court. 1994. Effect of transplanting date on the fatty acid composition, oil content and yield of evening primrose (*Oenothera biennis* L.) seed. Can. J. Plant Sci. 74: 129-131.

Simpson, M.J.A. and A.F. Fieldsend. 1993. Evening primrose: harvest methods and timing. Acta Horticult. 331: 121-128.

Uzzan, A. 1988. Borage oil and other plant oils rich in GLA: present status in Western Europe. Revue Française des Crops Gras – Paris (France). 35: 501-504.

Yaniv, Z. and M. Perl. 1987. The effect of temperature on the fatty acid composition of evening primrose (*Oenothera*) seeds during their development, storage and germination. Acta Horticult. 215: 31-38.

Yaniv, Z., R. Carmella, A. Levy and D. Palevitch. 1989. Effect of temperature on the fatty acid composition and yield of evening primrose (*Oenothera lamarckiana*) seeds. J. Exp. Bot. 40: 609-613.

Yin, X. and T.J. Vyn. 2005. Relationships of isoflavone, oil, and protein in seed with yield of soybean. Agron. J. 97: 1314-1321.

Weiss R.F. and V. Fintelmann. 2000. Herbal Medicine. Second Edition, revised and expanded. Georg Thieme Verlag. Germany.