

Maximizing Fennel Production: An Analysis of Sowing Date Effects on Growth, Yield, and Essential Oil Content

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Abstract

Fennel is a herbaceous plant widely used for both medical and aromatic purposes, owing to its economic and pharmacological benefits. This study investigated the effects of different sowing dates on the growth, yield, and quality of fennel plants under arid and semi-arid conditions of Aswan governorate. Three different dates were explored; 15th Oct, 1st Nov and 15th Nov for two successive seasons 2020/2021 and 2021/2022. The results showed that sowing date significantly influenced the vegetative and yield characters of fennel. Plants sowed on 15th Oct had the best growth and yield characteristics, including the tallest plants, the highest fruit weight per plant, and the highest fruit yield per Fadden. The highest percentage and yield of essential oil were observed in plants sowed on 1st Nov in the first season, and in plants sowed on 15th Oct in the second season. The findings suggest that sowing fennel on 15th Oct could lead to the highest yield and quality, which could be economically beneficial for farmers in arid and semi-arid regions.

Keywords: Fennel, sowing date, essential oil, fruit yield

Introduction

Fennel, scientifically known as *Foeniculum vulgare* Mill., is a perennial herbaceous plant that belongs to the *Apiaceae* (*Umbelliferae*) family. It is widely used for both medical and aromatic purposes, owing to its economic and pharmacological benefits. Fennel is grown extensively in many countries, including Romania, Russia, Germany, France, Italy, Argentina, the United States, India, Egypt, Syria, Morocco, Denmark, China, Bulgaria, and Japan (**Ghanbari et al., 2013**). In Sudan, it is mostly grown in the Northern State, consumed locally, and exported to the Gulf Nations (**FEWSN, 2011**). It is considered one of the most important commercial crops for export, and it is the top-ranked export of herbs and spices from Egypt in terms of quantity (**Basem et al., 2012**). Fennel was also one of the earliest field crops utilized by the Egyptians for therapeutic purposes. In Egypt, only one type of fennel (*Foeniculum vulgare*, Mill.) is grown for both domestic and foreign use (**Abu El-Leel and Yousef, 2017**). The crop is highly sought after throughout the world for use in cooking, medicine, and cleaning due to its high content of vitamin C, fiber, and potassium. Fennel has a significant market value and a long preservation time.

Climate change has been found to have a significant impact on the phytochemical content and composition of crops, depending on agronomic factors such as sowing date, fertilization, and

irrigation (Shrestha *et al.*, 2022). The impact of climate change on agriculture poses a significant threat globally, as it exacerbates both biotic and abiotic stresses that affect plant production. Reduced irrigation water, fluctuating rainfall patterns, warm spells, drought, and salinization all threaten the industry. Therefore, it is crucial to consider the effects of climate change and planting date on crop production and modeling to improve crop yields. Identifying the optimal planting time for new cultivars in each region is the most significant and controllable factor for maximizing crop yields, as stated in a study by Zhang *et al.* (2023). The selection of an appropriate planting time is crucial for optimizing plant growth stages and achieving maximum yield by utilizing natural resources efficiently during the growing seasons, according to a study by Safaei *et al.* (2017).

Agricultural production management emphasizes the importance of selecting the optimal time for cultivation. The objective of determining the sowing date is to identify the most favorable time for planting cultivars, where the prevailing environmental conditions are conducive to the germination and vitality of the plants, as stated in a study by Macdiarmid (2022). This study aimed to determine the appropriate date for planting fennel, *Foeniculum vulgare* Mill, to obtain the best growth and quality under arid and semi-arid condition of Aswan governorate.

Materials and methods:

This study had been conducted in the two successive seasons of 2020/2021 and 2021/2022 at Agricultural Experimental Farm, Faculty of Agriculture and Natural Resources, Aswan University, Aswan, Egypt (23°59'59.92"N, 32°51'38.07"E). Seeds of fennel, *Foeniculum vulgare* Mill, were obtained from the National Research Center of Egypt. The fennel seeds directly were sown in the field at three different dates; 15th Oct, 1st Nov., and 15th Nov. in both seasons (2020 and 2021).

Table (1). Indicate the average of temperature and relative humidity for the two growing seasons 2020/2021 – 2021/ 2022, climatic data were obtained from National Aeronautics and Space Administration (NASA), Earth Observing System Data and Information System (EOSDIS) website.

Table (1). Average temperature and relative humidity.

parameter and season	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
Average of temperature 1 st season	24.71	25.11	25.28	25.61	29.62	35.45	33.3	36.89
Average of temperature 2 nd season	29.87	24.6	17.53	14.3	17.01	20.7	30.31	34.08
average of relative humidity 1 st season	26.71	36.47	43.37	41.67	35.33	22.49	14.55	17.81
Average of relative humidity 2 nd season	22.88	39.94	39.75	39.56	35.5	24.19	16.69	12.81

About 3-4 fruits were used in cultivation to give 3-4 seedlings, Thinning was done after one month from sowing (two plants/hill) to be forty plant per plot. All agricultural practices were carried out according to the traditional recommendation of the Ministry of Agriculture. Plants were fertilized with 200kg ammonium nitrate, 50kg potassium sulfate, 250 Kg super phosphate triple.

Phosphorus was added to the soil during soil preparation, nitrogen was separated into three doses, while potassium separated into two doses during the vegetative growth. About 20 tons/Fadden of botanical source compost were added during soil preparation. Irrigation was in drip irrigation system with 16 mm pipeline and 4 liters per hour dripper's flow rate. Some mechanical and chemical analysis of soils was conducted (soil texture, N.P.K, Ph, EC).

Vegetative and yield characters

At the harvesting time of each season, the vegetative growth and yield characters were recorded including; plant height, stem diameter, number of branches/plant (on the main shoot of a plant), number of umbels per plant, shoot and root' fresh and dry weight per plant (in dry weight plants were dried in shady place for 15 days) and per Fadden, fruit weight/plant, and fruit yield/Fadden.

Essential oil analysis

The seeds (100g) were hydro-distillate using Clevenger-type apparatus for three hours (**Clevenger, 1928**). Essential oil content (%) and total essential oil yield per Fadden were calculated.

Statistical analysis

Data obtained were subjected to statistical analysis using the “F” Test (**Snedecor and Cochran, 1989**) and the means were compared using a least significant difference (L.S.D.) test according to (**Gomez and Gomez, 1984**). Statistical analysis was performed using the R software (version 2023, R Foundation for Statistical Computing, USA).

Results and Discussion

In this study, the vegetative and yield characters had significantly influenced by sowing date. The tallest plants were observed in plants sowed in 15th Oct in both seasons, while the shortest plant were observed when plants sowed in 15th Nov (Figure 1), In the same line, number of branches and number of umbels showed highest values when plants cultivated in 15th Oct and lowest values when cultivated in 15th Nov (Figure 1). Generally, stem diameter was wider in plants sowed in 1st Nov compared to other sowing dates (Figure 1). The highest shoot' fresh and dry weights were recorded under sowing date of 15th Oct, while the highest root' fresh and dry weight were recorded under sowing dates of 1st Non and 15th Oct in the first and second season, respectively (Figure 1). Many studies have shown that fennel sown at the optimal time results in better vegetative growth, increased plant height, stem diameter, leaf area, increased root length, surface area, volume. This can be beneficial for nutrient uptake and overall plant health, as well as, optimal sowing dates can impact nutrient better N, P, and K uptake in fennel, which can be beneficial for plant growth, higher umbel numbers, better cell and tissue development, resulting in improved plant health and stress tolerance, yield increase and higher essential oil content, which can be beneficial for medicinal and culinary uses (**El-Metwally, 2013; Lopez-Bellido, 2015; El-Saidy et al., 2016; Babae and Khaleghi, 2017; El-Danasoury, 2020**).

The economic part of fennel is the seeds formed in the inflorescences, which are metaphorically called the fruits, in addition to the essential oils extracted from them. The highest fruit weight per plant (approx. 16 g) was observed in plants sowed in 15th Oct at both season. The

highest fruit yield was approx. 700 and 713 kg per Fadden in the first and second season, respectively and were recorded in plants sowed in the 15th Oct in both season (Figure 2). On the other hand, the highest essential oil percentage (1.42%) and yield (4.75 L/Fadden) were recorded in plants when sowed in 1st Nov in the first season. In the second season, although the highest essential oil percentage (1.83%) was observed when plants sowed in 15th Nov., the highest essential oil yield (5.66 L/Fadden) was recorded in plants sowed in 15th Oct (Figure 3).

Overall, most studies suggest that October is the best sowing date for fennel in terms of growth, yield, and essential oil content. However, it is important to note that the optimum sowing date may vary depending on the specific climate and soil conditions of each location (**El-Sayed and El-Kersh, 2014**). It was found that sowing fennel in October resulted in higher plant height, number of branches per plant, and yield compared to other sowing dates. Similarly, **Ahmad et al. (2014)** showed that October sowing resulted in higher yield and essential oil content compared to other sowing dates. Furthermore, **Gajera et al. (2017)** reported that fennel sown in October had higher yield and essential oil content compared to other sowing dates. Sowing fennel in October resulted in better growth, yield, and oil content compared to other sowing dates. October-sown fennel had higher number of umbels, higher seed yield per plant, and higher essential oil content (**Singh et al., 2019**). Additionally, it was found that fennel sown in October had higher biomass, yield, and essential oil content compared to other sowing dates (**Sharma et al. 2019**).

Moreover, mid-November sowing date can have a positive impact on fennel yield and quality. Found that mid-November sowing date resulted in higher fennel yields compared to earlier sowing dates. This attributed to the lower temperatures during the vegetative growth period, which reduced the incidence of pests and diseases and improved plant growth (**El-Badawy et al., 2013**). Similarly, **Boroumand et al. (2017)** reported that mid-November sowing date resulted in higher fennel yield, essential oil content, and quality compared to other sowing dates. The mid-October (October 15th) sowing date was the best sowing date for fennel cultivation, best for fennel production, as it resulted in the highest yield and quality of fennel seeds and essential oil., was supported by (**El-Sayed and El-Kersh, 2014; El-Karamany and Mohamed, 2017; Youssef and Abdel-Mawgoud, 2018**). On the other hand, the mid-November sowing date may have a negative impact on fennel yield and quality. That mid-November sowing date resulted in lower fennel yield compared to earlier sowing dates. Attributed this to the shorter vegetative growth period and the adverse effect of low temperatures on plant growth and development (**El-Bassiony et al., 2012**). Additionally, it was found that mid-November sowing date resulted in lower fennel yield and essential oil content compared to earlier sowing dates (**Ghasemi et al., 2016**). While, the sowing fennel in late October to early November resulted in lower yields compared to sowing in early September (**Duman and Duman, 2017**).

Many studies have shown that fennel sown at the optimal time results in better vegetative growth, increased plant height, stem diameter, leaf area, increased root length, surface area, and volume. This can be beneficial for long time vegetative growth, general nutrient uptake and overall plant health, specifically optimal sowing dates can impact better N, P, and K uptake in fennel, which can be beneficial for plant growth, higher umbel numbers, better cell and tissue development, resulting in improved plant health and stress tolerance, yield increase and higher essential oil content, which can be beneficial for medicinal and culinary uses (**El-Metwally, 2013; Lopez-Bellido, 2015; El-Saidy et al., 2016; Babae et al., 2017; El-Danasoury et al., 2020**).

In conclusion, the results of this study demonstrate that the sowing date significantly affects the growth, yield, and quality of fennel plants under arid and semi-arid conditions. The optimal sowing date for fennel in this region appears to be 15th Oct, which resulted in the tallest plants, the

highest fruit weight per plant, and the highest fruit yield. Additionally, the highest essential oil yield was observed in plants sowed on 15th Oct in the second season, while the highest essential oil percentage was recorded in plants sowed on 1st Nov in the first season. These findings could be useful for farmers in arid and semi-arid regions who are interested in cultivating fennel for its economic and medicinal benefits.

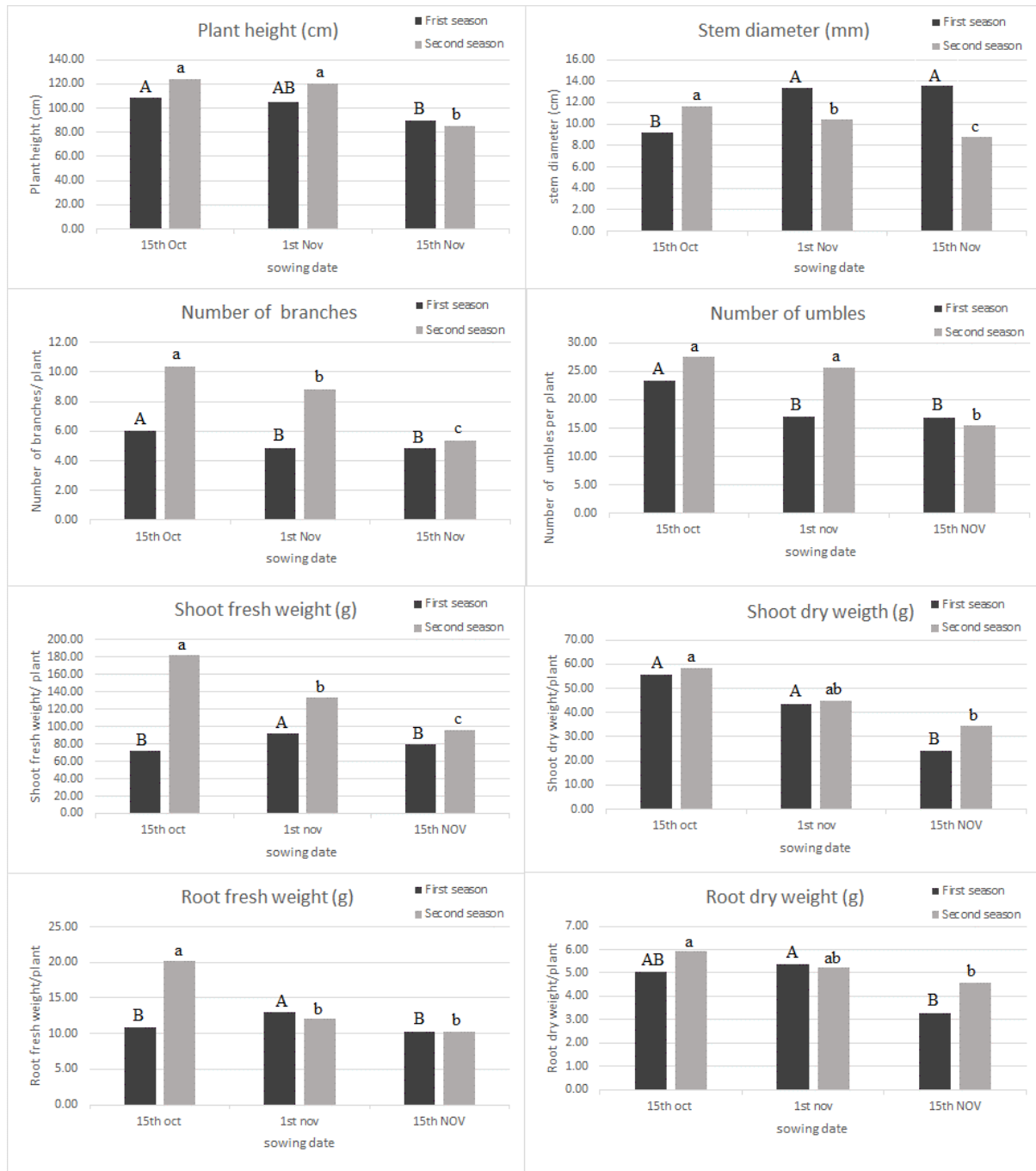


Figure (1): Effect of sowing date on the vegetative growth characters of fennel in the 2020/2021 and 2021/2022 seasons. Different letters means significant difference at probability of 5%.

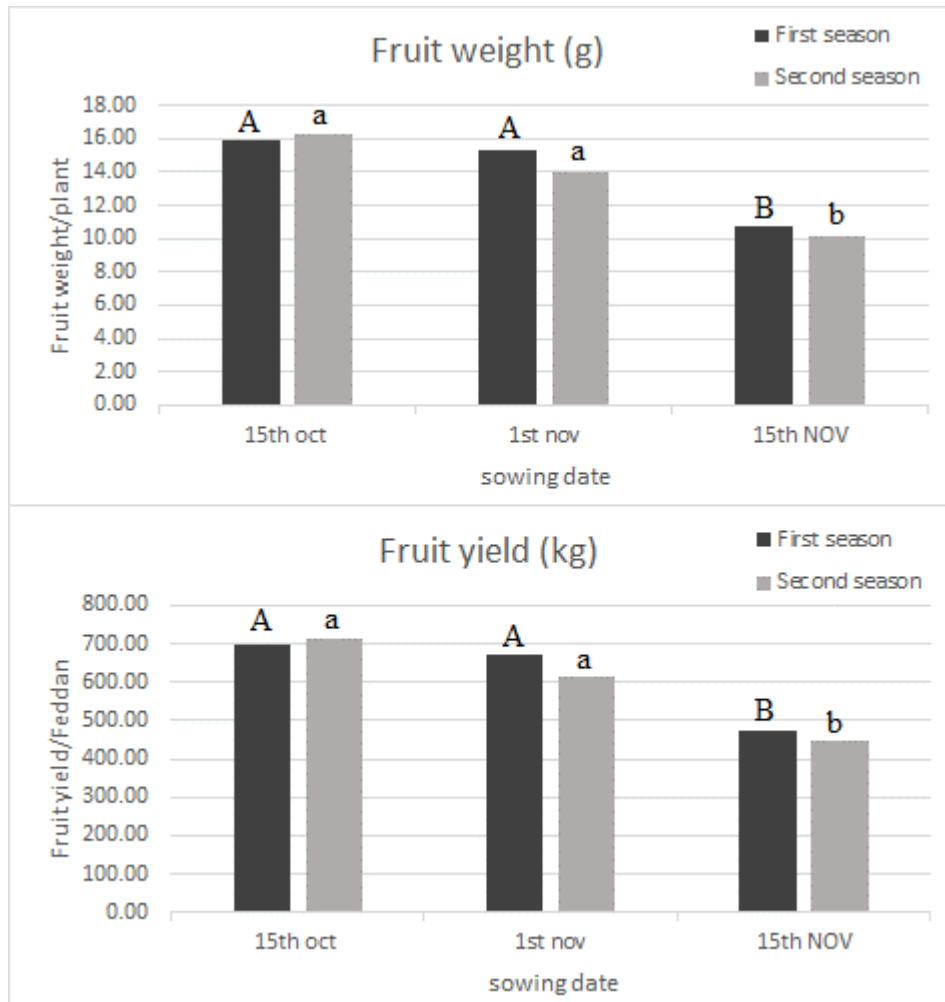


Figure (2): Effect of sowing date on the fruit weight/plant and fruit yield/Fadden of fennel in the 2020/2021 and 2021/2022 seasons. Different letters means significant difference at probability of 5%.

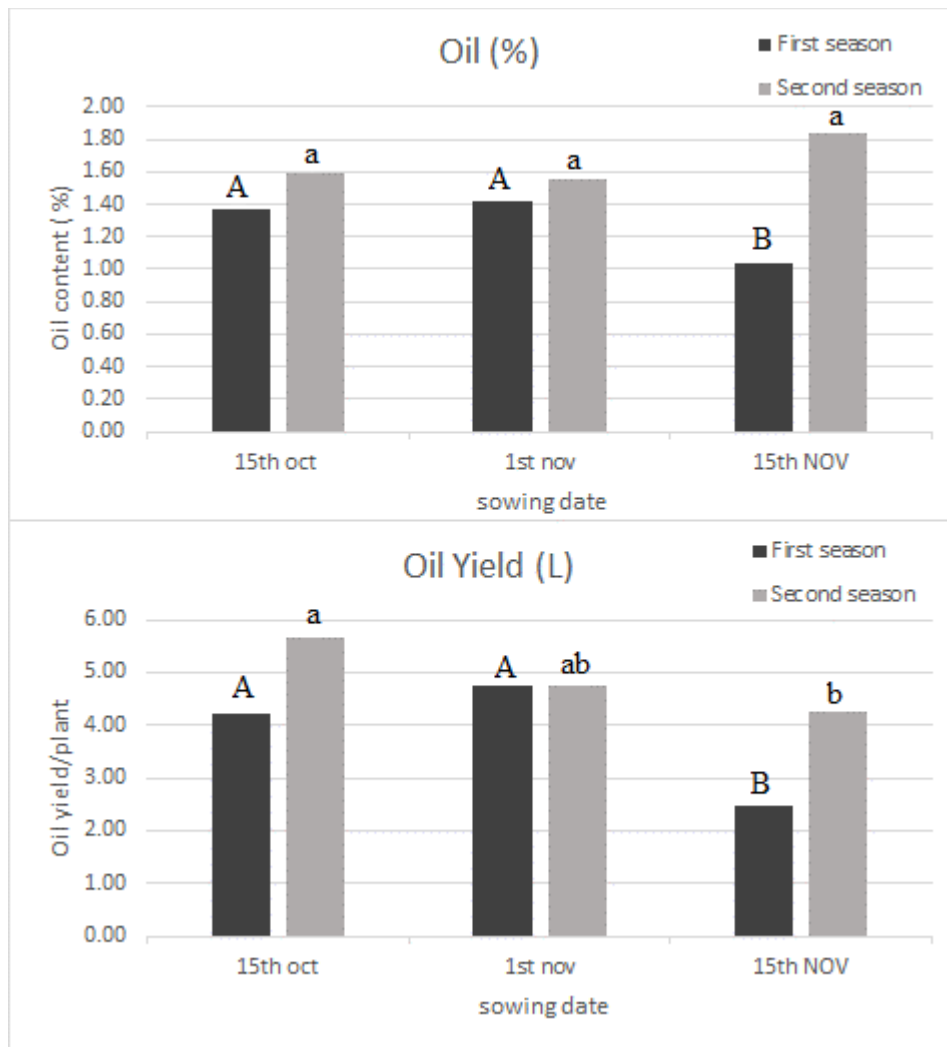


Figure (3): Effect of sowing date on the essential oil percentage and yield/Fadden of fennel in the 2020/2021 and 2021/2022 seasons. Different letters means significant difference at probability of 5%.

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