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Fruit and essential oil yield of fennel (*Foeniculum vulgare* Mill.), grown with fertilizer sources for organic farming in Egypt

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Abstract

The main objective of this study was to find out whether under Egyptian conditions sufficient and high qualities of fennel yields can be produced with the nutrient sources allowed by organic farming. Fennel an important medicinal plant grows well under Egyptian conditions and plays an important role for the export of the country.

The tested sources allowed by organic farming rules were for N: compost, compost + *azotobacter* and chicken manure compared with ammonium nitrate, for P: soft rock phosphate (rock-P) alone and rock-P mixed with elemental S compared with superphosphate and for K: feldspar compared with potassium sulphate.

Two field experiments were conducted in an area of newly reclaimed land near Cairo, and on old cultivated land near Giza in the Nile valley during two successive seasons (1998/1999 and 1999/2000).

The investigation yielded the following main result: although with N supplied by compost + *azotobacter*, P by rock-P+S and K by feldspar fennel yields tended to be lower but the essential oil yield was not affected significantly by fertilisation with organic or conventional sources of N, P and K.

The main conclusion of the research work is that at least from the viewpoint of plant nutrition fennel can be grown under the conditions of organic farming in order to improve the income of small farms in Egypt.

Key words: fennel, fertilisation, nitrogen, organic farming, phosphate, potassium, quality, essential oil

Zusammenfassung

Ertrag und Ölqualität von Fenchel (*Foeniculum vulgare* Mill.), gedüngt mit Nährstoffquellen des Organischen Landbaus in Ägypten

In der vorliegenden Arbeit wurde untersucht, ob es mit den Vorgaben des ökologischen Landbaus zur Düngung möglich ist, ausreichende und qualitativ hochwertige Fenchel-Erträge in Ägypten zu produzieren. Fenchel ist eine bedeutende Heilpflanze, die unter den klimatischen Bedingungen Ägyptens gut wächst und eine wichtige Einkommensquelle, insbesondere für kleinbäuerliche Landwirtschaft, darstellt.

Geprüft wurden Kompost, Kompost + *Azotobacter*, Geflügelmist, Rohphosphat (Roh-P), Roh-P in Mischung mit elementarem Schwefel und Feldspat als Quellen für N, P und K. Die Kontrollen wurden mit Ammoniumnitrat, Superphosphat und Kaliumsulfat gedüngt.

Die Feldversuche wurden in der Neuland-Region der Wüste in der Nähe von Kairo und auf seit langem landwirtschaftlich genutztem Land im Niltal in der Nähe von Giza während zweier Vegetationsperioden (1998/1999 und 1999/2000) durchgeführt.

Die Untersuchungen kamen zu folgendem hauptsächlichem Ergebnis: N verabreicht mit Kompost + *Azotobacter*, P mit Roh-P + S und K mit Feldspat ergab zwar tendenziell niedrigere Erträge an Fenchel als bei Düngung mit Ammoniumnitrat, Superphosphat oder Kaliumsulphat, der Ertrag an essentiellem Öl der Früchte war jedoch von den Kontrollen statistisch nicht verschieden.

Als Schlußfolgerung kann daher, zumindest aus Sicht der Pflanzenernährung, die Produktion von Fenchel in Ägypten nach den Regeln des ökologischen Landbaus empfohlen werden, um die Ertragslage kleinbäuerlicher Landwirtschaft und damit die Lebensqualität im ländlichen Raum zu verbessern.

Schlüsselworte: Düngung, essentielle Öle, Fenchel, Kalium, organischer Landbau, Phosphat, Qualität, Stickstoff

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1 Introduction

Fennel (*Foeniculum vulgare* Mill.) is one of the most important medicinal plants which grows well in Egypt and some European countries. Fennel is used in folk medicine as a stimulant, diuretic, carminative or sedative.

In eastern and western herbalism it is considered to be good for obstruction of the liver, spleen and gall bladder and for digestive complaints such as colic, indigestion nausea and flatulescence. Fennel may also be used as tea which increases the milk of nursing mothers (Blumenthal et al., 1999).

To meet the increasing demand of fennel large areas of newly reclaimed land have been cultivated with fennel (fig. 2). Also the intensive farming on Nile valley soils forced farmers to use more fertilisers. But the intensive use of manufactured nitrogen fertilisers - although increasing the productivity - reduced the acceptance of the crops for export to European pharmaceutical manufacturers who prefer material grown according to the standards of organic farming.

Therefore field trials have been started to investigate the possibilities of organic farming - like it is stated in the EU guidelines 2092/91 (Schmidt and Haccius, 1998) - for the production of fennel oil in Egypt. The effect of different nitrogen, phosphorous and potassium sources on seed yield and yield of essential fennel oil has been tested, respectively compost, compost with *Azotobacter* (bacteria injected into the soil), chicken manure and ammonium nitrate. Phosphorous fertilisation has been done with rock-P alone, rock–P mixed with sulphur(S) and super phosphate. Different potassium sources have been tested also, potassium given as natural source as feldspar or as chemical fertiliser in the form of potassium sulphate.

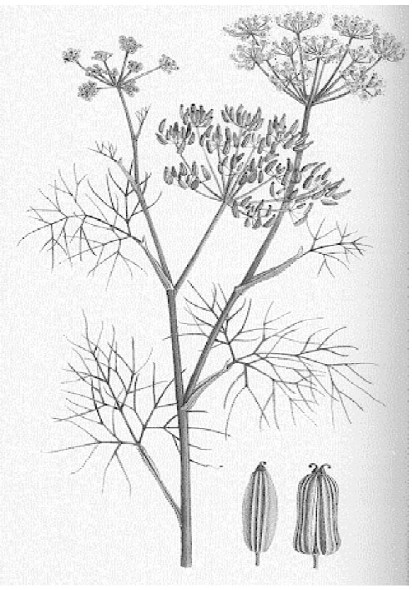

Fig. 1
Fennel (*Foeniculum vulgare* Mill.) (from Gäbler, 1982)

Fig. 2
Fennel cropping in the oasis Fayum, Egypt (front: fennel; back: wheat: far back sand dunes of the Sahara)

2 Material and Methods

A set of experiments were carried out in Egypt in an area of newly reclaimed land (sandy soil) in comparison with an old cultivated land in the Nile Valley (clay loam soil) during two successive seasons (1998/1999 and 1999/2000). The first experiment was performed in the farm of Sekem company at Heykastep (15 km east of Cairo). The major system of irrigation in this farm was drip irrigation system using water of the river Nile. The second experiment was performed in the experimental farm of the Pharmaceutical Sciences Department, National Research Centre, at Giza as a comparison site for the old cultivated lands in the Nile Valley, which was irrigated by Nile water using flood irrigation. The chemical and physical features of the two soils are shown in table 1.

Nitrogen was applied at the rate of 250 kg ha^{-1} N employing the following sources: compost and chicken manure were added in two portions, the first one during the preparation of soil before sowing and the second portion was added after three months from sowing date in both sandy and clay loam soils.

Azotobacter: fennel seeds inoculated directly before planting, and 20 or 45 days thereafter and received both cultures of *Azotobacter chroococum* and compost.

Phosphate fertiliser was added at the rate of 180 kg ha^{-1} P_2O_5 during the preparation of soil before sowing from the following phosphorus sources; rock phosphate alone, rock phosphate mixed with 120 kg ha^{-1} elemental S and calcium super phosphate (15.5 % P_2O_5).

Table 1
Some chemical characteristics of the soils of the sites before the treatments

Soil type	pH	Total C	Total N	P_2O_5	K_2O	Fe	Mn	Cu	Zn
		(%)		plant available content mg kg^{-1}					
Sandy soil (1998/1999)	7.9	0.92	0.034	25.0	10.7	3.4	9.2	1.9	1.8
Sandy soil (1999/2000)	7.8	1.88	0.141	98.0	24.0	6.0	20.0	1.5	9.4
Clay loam (1998/1999)	8.0	2.31	0.136	28.0	22.3	7.7	13.8	4.1	2.1
Clay loam (1999/2000)	8.1	2.10	0.163	29.0	18.8	8.1	14.7	3.6	2.0

Potassium fertiliser was applied at the rate of 120 kg ha^{-1} K_2O during the preparation of soil before sowing in form of feldspar and potassium sulphate (48 % K_2O).

The design of the experiment was a split-split plot with four replicates. The areas of sub-sub plot were (3x4m^2) on the experimental farm of the Pharmaceutical Department and one row (70 cm x 10 m) on the Sekem farm.

Foeniculum vulgare (Mill.) seeds were obtained from Sekem company, Egypt. In the first season the seeds were sown on October 20 and 22, 1998 on Giza and Sekem Farm respectively. Whereas, in the second season, the sowing date was on October 21 and 22 in Giza and Sekem farm respectively. Seeds of fennel were manually sown in rows (70 cm between rows). Germination was practically completed after 12 days from seed sowing. After 30 days plants were thinned to two plants per hill at 20 cm in between.

Essential oil was extracted using a Clevenger-type apparatus: 25 g of the crushed seeds suspended in 500 ml water were distilled for 3 h. Dry matter was calculated after drying the plant material at 60 °C until reaching constant weight.

Statistical evaluations were made employing the TUKEY test.

3 Results and Discussion

Nitrogen: The effect of different nitrogen sources on the performance of fennel is shown in table 2. Results showed that ammonium nitrate gave the highest seed yields in both seasons and on both soils. Fertilisation with compost on clay loam soil resulted in 17 % and 7 % less of the yield obtained after fertilisation with ammonium nitrate and 1 % and 12 % less on sandy soil in both growing seasons respectively. Application of chicken manure gave only 92 % from the yield of the plot fertilised with ammonium nitrate in both growing seasons and 98 % and 85 % on the sandy soil in the first and second growing season respectively. Compost had a similar effect as commercial fertiliser, providing the same amount of total N but could have released less available N, given the normal rate of mineralisation. Inoculating the clay loam soil with *Azotobacter* increased the fruit yield by 14 % and 5 % compared with fertilisation with compost alone. Results on sandy soil were been –3 % and +6 % respectively.

Yields of fennel oil showed the same trends as observed for the seed yields. Same results have been found by El-Hady et al. (1991), Dahdoh and El-Hassanin (1993) and Dahdoh and El-Demerdashe (1994). They found that

Table 2
Effect of nitrogen sources on yield and essential oil yield of fennel seeds grown on two sites in Egypt in 1998/1999 and 1999/2000

Nitrogen source	First season (1998/1999)		Second season (1999/2000)	
	Seed yield (kg ha^{-1})	Oil yield (l ha^{-1})	Seed yield (kg ha^{-1})	Oil yield (l ha^{-1})
	Clay loam soil			
Compost	2829 ^{c}	64 ^{c}	3152 ^{bc}	80 ^{b}
Chicken manure	3125 ^{b}	72 ^{b}	3079 ^{c}	73 ^{c}
Compost + *Azoto*.	3309 ^{ab}	81 ^{a}	3295 ^{ab}	82 ^{ab}
Ammonium nitrate	3389 ^{a}	77.5 ^{a}	3357 ^{a}	86 ^{a}
	Sandy soil			
Compost	3161 ^{ab}	69 ^{a}	2606 ^{b}	68 ^{b}
Chicken manure	3099 ^{ab}	62 ^{b}	2803 ^{b}	67 ^{b}
Compost + *Azoto*.	2988 ^{ab}	60 ^{b}	3007 ^{ab}	81 ^{a}
Ammonium nitrate	3164 ^{a}	71 ^{a}	3304 ^{a}	86 ^{a}

Table 3
Effect of phosphate sources on yield and essential oil yield of fennel seeds grown on two sites in Egypt in 1998/1999 and 1999/2000

Phosphate source	First season (1998/1999)		Second season (1999/2000)	
	Seed yield (kg ha^{-1})	Oil yield (l ha^{-1})	Seed yield (kg ha^{-1})	Oil yield (l ha^{-1})
	Clay loam soil			
Rock phosphate	3102 ^{b}	72 ^{b}	3213 ^{ab}	80 ^{b}
Rock phosphate +S	3026 ^{b}	72 ^{b}	3274 ^{a}	84 ^{a}
Super-phosphate	3299 ^{a}	77 ^{a}	3116 ^{b}	74 ^{c}
	Sandy soil			
Rock phosphate	2994 ^{b}	66 ^{a}	3089 ^{a}	83 ^{a}
Rock phosphate +S	3117 ^{ab}	63 ^{b}	2958 ^{ab}	73 ^{b}
Super-phosphate	3224 ^{a}	68 ^{a}	2744 ^{b}	69 ^{b}

organic materials such as FYM and S.S. increased the yield of the grown plants. In general, the increase of the seed yield due to the addition of organic materials are a true reflection of: (a) improving soil aggregation and increasing water stable aggregates (Mostafa, 1986), (b) increasing the soil water retention due to its effect on pore size distribution, i.e. water holding capacity (Gouda, 1984), (c) improving the dynamic soil-water characteristics, i.e. decreasing the downward water movement through infiltration (El-Touky, 1982) and its upward movement via evaporation (Ahmed, 1990) and (d) contribution of organic matter to chemical properties and nutrition status in soils. The latter contribution include: (1) decrease in soil pH which leads to solubilisation of nutrients and increases nutrient availability and supply (Salem, 1986), (2) organic matter as a complexing agent, thus minimizes the loss of nutrients by leaching (Balba, 1973) and (3) stimulates bio-degradation through increasing the populations and activities of micro-organisms in the soil (Amara and Dahdoh, 1995).

Phosphate: The data presented in table 3 show that the application of super-phosphate gave the highest seed and oil yields in the first season on both soils. In the second season the fertilisation with rock-P plus S gave the highest yields on clay loam soil. In the case of P uptake rock-P tended to show its superiority over super-phosphate. No significant differences were observed in seed and fennel oil yields due to the fertilisation with rock-P alone or rock-P plus S in both seasons on both soils. Application of S decreased the fennel seed yield by 2 % in the first season on the clay loam soil and by 4.6 % in the second season on the sandy soil. The reduction of yields due to application of S may be attributed to more leaching rate of available phosphate especially in sandy soils which are characterised having low capacity of adsorbing nutrients. El-Laboudy and Omer (1975) pointed out that S applied at all rates was favourable for obtaining a relatively low soil pH. Decreasing soil pH may increase phosphate leaching into ground water especially in sandy soil. Eghaball et al. (1996) found P movement to 1.8 m soil depth following long term manure application. Compost or chicken manure application to provide for fennel N requirements may greatly increase soil level of P and other ions. The same results were obtained with corn plants by Eghaboul et al. (1997).

Potassium: Data presented in table 4 indicate that the fertilisation with feldspar or potassium sulphate gave no significant differences in seed and oil yields in both growing seasons on sandy soil. While the fertilisation with natural potassium source (potassium feldspar) on clay loam soil resulted in 7.5 % and 6.3 % less of the fruit yield obtained after fertilisation with the chemical fertilisation (potassium sulphate) and 18.5 % and 22.4 % less oil in the first and second season respectively. These results are in conformity with that reported by Ciompi (1997) who found no significant differences in K content of plants between K supply in solution or as feldspar in either N-sufficient or N-deficient sunflower plants. On the contrary Alafifi (1996) found that a negative relation between K-feldspar and the ready exchangeable K, indicating that K-feldspars contributed little to available K in soil. Also Bakken et al. (1997) stated that, application of potassium as feldspar was nearly unavailable to plants. Barman et al. (1992) found that organic acids such as oxalic, citric, salicylic and glycine dissolve minerals by a combined action of complexation and acid attack. In the case of K uptake feldspar tended to show its superiority over potassium sulphate under organic fertilisation.

4 Conclusions

Although with N supplied by compost + *azotobacter*, P by rock-P+S and K by feldspar, fennel yields tended to be lower, essential oil yield and main components in fennel

Table 4
Effect of phosphate sources on yield and essential oil yield of fennel seeds grown on two sites in Egypt in 1998/1999 and 1999/2000

Nitrogen sources	First season (1998/1999)		Second season (1999/2000)	
	Seed yield (kg ha^{-1})	Oil yield (l ha^{-1})	Seed yield (kg ha^{-1})	Oil yield (l ha^{-1})
		Clay loam soil		
Feldspar	3048 [b]	71 [b]	3122 [b]	76 [b]
Potassium sulphate	3279 [a]	77 [a]	3319 [a]	93 [a]
		Sandy soil		
Feldspar	3099 [a]	66 [a]	2926 [a]	78 [a]
Potassium sulphate	3106 [a]	67 [a]	2934 [a]	73 [a]

fruit oil (Kandil, 2002) were not affected significantly by fertilisation with organic or inorganic sources of N, P and K.

The main conclusion of the research work is that at least from the viewpoint of plant nutrition fennel can be grown under the conditions of organic farming in order to improve the income of small farms in Egypt.

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