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Effects of Different Nitrogen Doses on the Agricultural and Chemical Properties of Fennel (*Foeniculum vulgare* Mill.)

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Fertilization is one of the main factors affecting yield and quality in medicinal and aromatic plants like in other traditional crops. In this concept, the effects of four different nitrogen doses (0, 20, 40 and 60 kg ha^{-1}) on the yield and quality of fennel were investigated. Field trials were conducted by completely randomized design with three replications at experimental area located in Gevas-Cicekli district of Van, Turkey, in the years of 2001 and 2002. In this study, plant height, the number of branches, the number of umbrella, seed yield and essential oil yield of fennel were investigated. As a result, the highest plant height (59.3 cm) and essential oil yield (13.9 L ha^{-1}) values were determined in 60 kg ha^{-1} nitrogen application. The highest the number of branches (6.1 branches $plant^{-1}$), the number of umbrella (10.98 umbrellas $plant^{-1}$) and seed yield 665.0 kg ha^{-1}) values were obtained from 40 kg ha^{-1} nitrogen application.

Key Words: Fennel, Nitrogen, Seed yield, Essential oil.

INTRODUCTION

Because of negative side effects of chemicals on human health, medicinal and aromatic plants have recently been used as natural medicine, preservative, fragrant and other purposes. Medicinal and aromatic plants can be found in the nature in big quantities, some of them are cultivated in the fields and they have a wide range of usage area, so their importance have gradually increased. They have 14 billion US dollars trade volume on the worldwide. Of this amount, more than one billion US dollars belongs to essential oils[1]. Of the total essential oil production on the worldwide, 3 % is used in pharmaceutical, 34 % is consumed in beverage and rest of them are used in other industries such as cosmetic, perfumery, *etc.*[2].

Although Turkey is one of the richest countries aspects of plant genetic diversity, more than 70 % of the raw plant materials commonly used in medicine and other industries have been imported from other counties[3]. While a few medicinal and aromatic plant species such as anise, black

cumin, coriander, fennel, fenugreek have been cultivated in small fields, big quantities of medicinal plants currently been collected from nature in Turkey. Cultivation of this plant group has a special importance for conserving natural plant genetic diversity and producing standard plant products[4].

Fennel is an important medicinal, spice and vegetable plant. Essential oil and seed fatty oils are mainly used in food, cosmetic, perfumery and pharmaceutical industries. Fennel is known as raziyane and rezene in Turkey and it has commonly been used in folk medicine[5,6]. Its fruit and derivatives are used for producing anizet, a kind of alcoholic beverages, candies, bakeries and non-alcoholic drinks as well. Fennel has a number of pharmaceutical properties such as gastrointestinal, sedative and carminative. Its fruits are used in infusion (1-2 %) for these purposes in Turkey[7]. Because of its sedative and carminative effects, fennel tea is very popular for baby teas in Turkey and European countries.

Nitrogen is a common plant nutrition which promotes vegetative developments in crops. This nutrient is also important for producing herba and folium yields in medicinal plants[8]. Because of its negative effects on essential oil content and composition, excessive nitrogen applications is not recommend for essential oil plants[9,10].

Although Van province, one of the biggest centers of Eastern Anatolia of Turkey, has big production area, a few common crops have been cultivated. Cultivation of medicinal and aromatic plants in the region is very important by means of crop diversity and rotation, increasing job opportunities with high income crops. In the present study, the effect of different nitrogen doses on the yield and quality of fennel grown in Van conditions was studied.

EXPERIMENTAL

Seed material of fennel (*Foeniculum vulgare* Mill.) was obtained from Cukurova University Agricultural Faculty Field Crops Department, Adana, Turkey. Field trials were conducted at experimental area located in Gevas-Cicekli district of Van in 2001 and 2002. Soil properties of the experimental were sandy-loamy with low organic matter (1.01-1.41 %). Phosphorus content was low (7.12-7.21 ppm), lime content was high (19.0-21.9 %) and light alkaline (pH 7.70-7.79)[11]. According to meteorological data of the region, climate values were as follows: total rainfall, 326.4 and 390.1 mm; average temperature, 11.1 and 14.6 °C and humidity in the air, 45.4 and 58.9 % in the experimental years, respectively. More rainfall received during the vegetation period (252.5 mm) in the second experimental year than the first one (116.0 mm) and rainfall distribution was irregular[12].

Field trials were designed according to completely randomized design[13] with three replications. As factorial, four different nitrogen doses (Control - 0, 20, 40 and 60 kg ha^{-1}) in ammonium sulphate (21 % N) form were

applied to plots. Each plot were also applied a 60 kg P_2O_5. Seeds were sown by hand in May 3, 2001 and May 10, 2002 in the experimental years. Each plot sizes were 3 m × 2 m = 6 m^2 and row spacing was 40 cm in 5 rows. Area harvested was 2.4 m^2 and plants were harvested by hand when seeds were ripened. All the necessary cultural practices were applied the plots during vegetation period.

In the study, some agricultural and chemical traits such as plant height (cm), the number of branches (branches $plant^{-1}$), the number of umbrellas (umbrella $plant^{-1}$), the number of seeds in umbrella (seeds $umbrella^{-1}$), seed yield (kg ha^{-1}), thousand seed weight (g), seed essential oil content (%) and seed essential oil yield (L ha^{-1}) were investigated. While some agricultural traits were determined on the field before harvest, technical analysis were done in the laboratory. Essential oil content in the seeds as volumetric was determined by Neo-Clevenger type apparatus in 20 g seeds with 2 h. Essential oil yield was calculated by seed yield and essential oil content. All the data obtained from the field trials and laboratory analyses were statistically evaluated by MSTATC computer program. LSD (Least Significant Differences) with 1 % probability levels was used for comparisons[14].

RESULTS AND DISCUSSION

Overall statistical analyses showed that there were significant differences between the years for plant height, the number of seeds in the umbrella and seed yield except the other traits examined. All the traits investigated in this study were positively affected by varying nitrogen doses except for the number of branches and essential oil content.

Plant height: There were significant differences between the plant height values of fennel in the experimental years. Average plant height values varied in the intervals of 51.3-55.6 and 48.3-63.4 cm in 2001 and 2002, respectively (Table-1). Higher plant height values were measured in the second year. These differences in the average plant height values could be explained by the different rainfall regimes in the years. Increasing nitrogen doses increased plant height of fennel in both years. According to two year average values, the highest plant height (59.3 cm) was measured in 60 kg ha^{-1} and the lowest plant height (49.8 cm) was obtained from control plots. It is the phenomenon that nitrogen promotes vegetative development and increases plant height in plants. In this concept, higher nitrogen doses yielded higher plant heights in this study.

Plant height of fennel was reported in different studies as follows: 60-200 cm[15], 66.5-70.7 cm[16], 88.1-94.1 cm[17], 45.4-50.5 cm[18], 58.4-77.1 cm[19]. The present results are in harmony with the researchers' findings; however, some differences can be seen among the plant height values. As known, plant height is a trait which related to plant genotype and easily affected by

ecological variations in growing conditions and cultural applications. So, differences in plant height among the different ecological and soil conditions with different seed populations could be expected.

Number of branches: The effect of varying nitrogen doses on the number of branches of fennel was significant experimental years and their averages. The number of branches increased by increasing nitrogen doses up to 40 kg ha^{-1}, there was slight decrease in further nitrogen doses (Table-1). According to two-year averages the number of branches varied from 5.3 to 6.1 branches $plant^{-1}$ and the highest value (6.1 branches $plant^{-1}$) was obtained from 40 kg ha^{-1} nitrogen dose. In the study, increased nitrogen doses were supposed to encourage vegetative development and branch formulations. Kirici *et al.*[20] reported that higher nitrogen doses than 60 kg ha^{-1} had negative effect on the branches number in coriander. In the related studies, the number of branches of fennel was reported in the range[1,18,19] of 4.3-12.8 branches $plant^{-1}$. Branches values determined in the present study are in harmony with the researchers' findings.

TABLE-1
AVERAGE VALUES OF PLANT HEIGHT AND
THE NUMBER OF BRANCHES OF FENNEL

Nitrogen doses (kg ha^{-1})	Plant height (cm)			Number of branches (branches $plant^{-1}$)		
	2001	2002	Mean	2001	2002	Mean
0	51.3	48.3 c	49.8 c	5.3 b	5.4 b	5.3 b
20	53.9	55.6 b	54.8 b	5.4 b	5.5 b	5.4 b
40	55.6	55.9 b	55.8 b	5.9 a	6.2 a	6.1 a
60	55.2	63.4 a	59.3 a	5.3 b	6.2 a	5.8 a
Nitrogen mean	54.0	55.8	–	5.5 b	5.8 a	–
LSD (5 %)	Ns	4.28	2.76	0.46	0.51	0.31

There were no significant differences between the mean values shown the same letters in 5 % probability level.

Number of umbrellas: Varying nitrogen doses significantly affected the number of umbrellas of fennel. As the highest the number of umbrellas (10.98 umbrellas $plant^{-1}$) was determined in 40 kg ha^{-1} nitrogen doses, the lowest value (8.6 umbrellas $plant^{-1}$) was obtained from control plots in two-year averages (Table-2). The number of umbrellas is directly affected the number of branches in fennel. In optimum growing conditions plants can produce more fruitful branches. In the present study, the number of branches increased by increasing nitrogen doses and they produced more umbrellas. However, some slight decrease in the number of umbrellas occurred in higher nitrogen doses than 60 kg ha^{-1} like branches number.

The number of umbrellas of fennel was reported in different studies in the range[1,18,19] of 1.6-64.9 umbrellas plant^{-1}. Variation in the number of umbrellas of fennel obtained from different growing conditions and regions is an expected result. So, the some plant variety could also be produce different branches and umbrellas number in varying growing conditions.

Number of seeds in umbrellas: As shown in the Table-2, varying nitrogen doses had significant effect on the number of seeds in umbrella of fennel. The number of seeds in the umbrella varied from 62.43 to 82.01 seeds umbrella^{-1} and the highest value was obtained from 60 kg ha^{-1} nitrogen doses. In the experimental years, the lowest seed numbers were determined in the control plots. The present results are in harmony with the previous reports[18,19]. Seed production of the crops is significantly affected by temperature and rainfall during generative stage period besides growing conditions. In dry and hot seasons, plants could produce lower seed yields even in optimum growing conditions.

TABLE-2
AVERAGE VALUES OF THE NUMBER OF UMBRELLAS AND THE NUMBER OF SEEDS IN UMBRELLA

Nitrogen doses (kg ha^{-1})	Number of umbrellas (umbrellas plant^{-1})			Number of seed in umbrella (seed umbrella^{-1})		
	2001	2002	Mean	2001	2002	Mean
0	8.30 c	9.03 c	8.60 c	58.83 b	65.50 b	62.43 b
20	9.50 b	10.86 b	10.18 b	61.86 b	66.03 b	63.48 b
40	9.60 b	12.40 a	10.98 a	79.73 a	79.00 a	79.36 a
60	10.70 a	11.13 a	10.91 a	83.66 a	80.36 a	82.01 a
Nitrogen means	9.51 b	10.85 a	–	71.02	72.72	–
LSD (5 %)	0.74	0.83	0.51	9.03	7.16	7.16

There were no significant differences between the mean values shown the same letters in 5 % probability level.

Thousand seed weight: The effect of increasing nitrogen doses on thousand seed weight of fennel was significant in year 2001, but the second experimental year and average of the years there were no significant differences. According to two-year averages the highest thousand seed weight (8.16 g) was obtained from 20 kg ha^{-1} nitrogen doses (Table-3). In related studies, thousand seed weight of fennel was in a wide range[6,15,19,21] of 3.8-9.55 g. A number of factors such as different seed populations, growing conditions, varying agricultural techniques could cause this big variation in thousand seed weight. Nevertheless, optimum growing and soil conditions increase dry matter accumulation in the seeds and thousand seed weights.

Seed yield: Seed yield values obtained from two-year field trials are given in Table-3. In the study, varying nitrogen doses significantly affected the seed yield of fennel. Seed yield increased by increasing nitrogen doses and the highest seed yield (665.0 kg ha^{-1}) was obtained from 40 kg ha^{-1} fertilizer application. There were no statistical differences between the 40 and 60 kg ha^{-1} nitrogen doses. Seed yield of the plants are as a result of yield components such as the number of branches, the number of umbrellas, thousand seed weight. These components were affected by nitrogen applications and as a result produce high seed yield in higher nitrogen doses.

TABLE-3
AVERAGE VALUES OF THOUSAND SEED WEIGHT AND SEED YIELD OF FENNEL

Nitrogen doses (kg ha^{-1})	Thousand seed weight (g)			Seed yield (kg ha^{-1})		
	2001	2002	Mean	2001	2002	Mean
0	7.20 b	8.3	7.75	468.0 d	502.0 d	484.8 c
20	8.50 a	7.8	8.16	564.0 c	613.6 c	589.0 b
40	7.20 b	8.3	7.75	606.0 b	724.0 a	665.0 a
60	8.00 ab	7.7	7.86	641.0 a	674.0 b	657.0 a
Nitrogen means	7.70	8.1	–	569.0 b	628.0 a	–
LSD (5 %)	1.21	Ns	Ns	28.4	37.4	21.6

There were no significant differences between the mean values shown the same letters in 5 % probability level.

Previous studies[20,22-24] in nitrogen fertilization in crops that nitrogen application increases seed yield, but higher doses have negative effects on the seed yield. In different studies fennel seed yields were given as follows: 920 kg ha^{-1} [25]; 439-589 kg ha^{-1} [26]; 700-2200 kg ha^{-1} [15]; 1500-3400 kg ha^{-1} [27]; 528 kg ha^{-1} [16]; 638-860 kg ha^{-1} [28]; 569-1671 kg ha^{-1} [18]; 264.3-586.7 kg ha^{-1} [1].

Seed essential oil content: The effect of varying nitrogen doses on the seed essential oil content of fennel was not significant in the experimental years. As the lowest seed essential oil content (2.01 %) was found in 40 kg ha^{-1} nitrogen dose, the highest value (2.12 %) was determined in 60 kg ha^{-1} nitrogen application (Table-4). Kirici *et al.*[20] stated that there were no statistical differences among the different nitrogen doses in coriander. In the present study, essential oil contents of fennel varied from 2.01 to 2.12 %. According to studies on fennel, seed essential oil content varies from 1.58 to 6.00 %[6,15,16,18,19,21,29]. Essential oil content of fennel obtained from varying nitrogen doses in this study in common ranges which states different studies. Furthermore, essential oil content is a highly variable trait in aromatic plants like fennel. So, big variation for essential oil contents from different studies could be expected.

Essential oil yield: Increasing nitrogen doses affected the essential oil yield of fennel in experimental years. As the highest value (13.9 L ha^{-1}) was obtained from 60 kg ha^{-1} nitrogen application, the lowest one (9.7 L ha^{-1}) was determined in unfertilized control plots (Table-4). There were no statistical differences between the 40 kg ha^{-1} and 60 kg ha^{-1} nitrogen applications. Essential oil yield is calculated from seed yield and essential oil content. Thus, variation in these traits directly affects the essential oil yield. Having positively affected by increasing nitrogen applications, seed yield of fennel caused to rise essential oil yield.

TABLE-4
AVERAGE VALUES OF SEED ESSENTIAL OIL CONTENT AND SEED ESSENTIAL OIL YIELD OF FENNEL

Nitrogen doses (kg ha^{-1})	Essential oil content (%)			Essential oil yield (L ha^{-1})		
	2001	2002	Mean	2001	2002	Mean
0	2.02	2.04	2.03	9.3 c	10.2 c	9.7 c
20	2.18	2.00	2.09	12.3 b	12.2 b	12.3 b
40	2.07	1.94	2.01	12.5 b	14.1 a	13.3 a
60	2.14	2.08	2.12	13.7 a	14.1 a	13.9 a
Nitrogen means	2.10	2.01	–	11.9 b	12.6 a	–
LSD (5 %)	ns	ns	ns	0.7	1.6	0.8

There were no significant differences between the mean values shown the same letters in 5 % probability level.

Conclusion

Among the few medicinal and aromatic plants cultivated in Turkey, fennel has traditionally been grown in small fields. There were no exact cultural techniques for this crop as well. Determining of agricultural techniques such as fertilization, irrigation, harvest time is very important in medicinal and aromatic plants in which quality is mainly considered. Thus, this study is a special significance for determining the effects of nitrogen application on agricultural and chemical properties of fennel. In the present study, fennel was grown in Van ecological conditions located in Eastern Anatolia of Turkey in year 2001 and 2002. Four varying nitrogen doses including control were applied to plots. In conclusion, increasing nitrogen doses positively affected plants height, the number of branches, the number of umbrellas and the number of seeds in umbrella, seed yield and essential oil yield of fennel. Of the investigated traits of fennel, the number of branches, the number of seeds in umbrella, seed yield and essential oil yield were positively affected up to 60 kg ha^{-1} nitrogen applications; however, the effects of further nitrogen doses than 40 kg ha^{-1} on the investigate traits were not statistically important. Thus, 40 kg ha^{-1} nitrogen doses for obtaining

high yield and essential oil in fennel could be advised. Further agricultural and technological studies should be developed for obtaining fennel with high yield and quality.

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