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IMPACT OF NITROGEN FERTILIZER ON THE PRODUCTIVITY AND QUALITATIVE PARAMETERS OF ANISE (*Pimpinella anisum* L.)

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ABSTRACT

The present study investigated the effects of nitrogen fertilization on the yield and quality characteristics of Anise (*Pimpinella anisum* L.). The study was conducted in the ecological conditions of Kahramanmaras from 2019 to 2021. Two different anise populations Izmir (P1) and Konya (P2) and six different nitrogen fertilizer doses (0, 30, 60, 90, 120, 150 kg ha^{-1}) were used in the study. The experiment was set up in Randomized Complete Block Design in 3 replications arranged in split plots, with the populations on the main plots and the fertilizer doses on the subplots. Considering the herbal properties of anise grown in different nitrogen dose applications; plant height was 41.7- 42.7 cm, the total number of branches (10.6-12.5 plants^{-1}), fruit branches (4.8-5.3 plants^{-1}) and umbrellas (8.1-9.6 plants^{-1}) were recorded. Considering the yield and quality characteristics; seed yield the range was 351- 400 kg ha^{-1}, 1000-seed weight 2.8-3.5 g, protein content 15.3-17.8%, fixed oil content 15.1-16.3% fixed oil yield 55.2-64.9 kg ha^{-1}, essential oil content 1.7-2.3%, and essential oil yield 5.8-8.9 L ha^{-1}. The Konya population had higher values in terms of seed yield and quality characteristics. With the exception of plant height, which revealed the total number of branches, fruit branches, umbels, seed yield, thousand seed weight, protein content, fixed oil content, fixed oil yield, essential oil content, and essential oil yield, all of the studied characteristics generally showed improvement with an increase in nitrogen doses. However, a nitrogen treatment of 120 kg ha^{-1} produced the maximum seed production.

Keywords: Anise, nitrogen, fertilization, *Pimpinella* sp., yield

INTRODUCTION

Anise (*Pimpinella anisum*) is a member of the Umbelliferae family and is one of the world's most important medicinal herbs. Although the exact origin of anise is uncertain, it is widely used in Egypt, Syria, Cyprus, Greece, the Crete Islands, and Turkey (Sonmez, 2018). Turkey has 31 taxa (8 of which are endemic), 26 species, 5 subspecies, and 4 variations of the genus *Pimpinella* (Guner et al., 2012; Boztas and Bayram, 2021). Anise has a weak root system, a stem that can grow up to 30-60 cm, and three-part, deeply toothed leaves. Each plant produces 5-15 branches and umbrella-shaped flower clusters at each branch tip. Anise fruit consists of two parts (carpel) and essential oils are stored in the schizogenic oil channels in the fruit seed (Baydar, 2020).

Since ancient times, the anise plant has been used as a food, spice, perfume, medicine, soaps, detergents, creams, and lotions. It removes the bad odors of cosmetics and medicinal herbs. Due to its many advantages and capacity to disguise flavors and smells, its fruit is used in the pharmaceutical business and in everyday nutrition (Baytop, 1984; Akgul, 1993). The body naturally accepts the naturally generated substances, which are increasingly used as a treatment alternative for a variety of illnesses, including viral infections (Chahande et al., 2022). Traditional flavored wines commonly include aniseed as an aromatic component (Liang et al., 2021). Aniseeds are also often used as an aromatic plant to flavor a range of dishes, including soups, poultry, pickles, salads, drinks, and confectionery items, imparting a licorice taste (chewing gum, jelly beans, and candy) (Mohamed and Koriem, 2015). The parts of anise used are the seeds and essential oil. Anise seeds are called fruit in the pharmaceutical trade and pharmacopeia (*Fructus anisi*) (Dogramaci and Arabaci, 2015). Turkish traditional medicine has used anise, especially its seeds, as a digestive, diuretic, and sedative (Arslan et al., 2004). Anise can also be used to treat cough, bronchitis, and asthma (Bhuvaneshwari et al., 2002). Plant nutrition is one of the most important factors in increasing plant output. Nitrogen (N) is the element that plants use most frequently because it is a part of the structure of the protein molecule. Significant chemicals like coenzymes, pyrimidines, purines, and porphyrins may also contain it. RNA and DNA contain purines and pyrimidines, which are necessary for the synthesis of proteins. Things essential for metabolisms, like cytochromes and the chlorophyll pigments needed for photosynthesis and respiration, contain the porphyrin structure (Khalid, 2013). Increased vegetative growth, essential oil, fixed oil, total carbohydrates, soluble sugars, and NPK concentrations are all consequences of nitrogen fertilization in different Apiaceae (anise, coriander, and sweet fennel) (Khalid, 2013). It's essential to produce anise correctly since several ecological and genetic variables have an impact on its economic fruit output (Iran-Nejad and Schahbazian, 2006). When compared to the control, Khalid (2013) found that nitrogen sprays dramatically boosted plant height, the number of branches, the number of umbrellas, and fruit yield. The productivity, nitrogen, and protein content of plants normally rise as nitrogen application increases (Ehsanipour et al., 2012). In order to grow therapeutic plants, fertilization is crucial. One of the most crucial aspects of fertilizing is maintaining good quality, active ingredients, essential oil, and plant or seed production. Conscious and balanced fertilization will increase production and quality (Yagmur, 2009). According to Izgi (2020), nitrogen is one of the macro components useful for growth, yield, and seed quality (Marschener, 1995). Nitrogen, after water, is the second-most significant component influencing the development and quality of medicinal plants, according to Merajipoor et al. (2020). Killi (2004) reported that the nitrogen rates to be applied in the study are specific to the region studied and are affected by environmental conditions.The current study was designed to determine how anise's yield and quality characteristics are affected by increasing nitrogen doses.

MATERIALS AND METHODS

To determine the effects of increased nitrogen fertilizer doses on the production and quality traits of two distinct anise populations, six different nitrogen fertilizer doses 0, 30, 60, 90, 120, and 150 kg ha^{-1} were administered in the current research. The research was conducted for two years in the growing season of 2019-2020 and 2020-2021.

Experimental Site and Conditions

The investigation was conducted two times in the Faculty of Agriculture, Field Crops Department's Research and Application Land at Kahramanmaras Sutcu Imam University. The average temperature of the experimental site in the growing season of the year 2019-20 was 13.3°C, while in 2020-21 it was 13.6°C. The average temperature recorded for the experimental site in both years was the highest for many years as shown in Table 1. In the case of precipitation, the first year (2019-20) precipitation recorded was 652 mm, which was the highest for many years. However, in the year 2020-21, the precipitation recorded was 543 mm, which was the lowest for many years. (Table 1). Regarding the analysis of the soils taken from 0-30 cm depth in the trial area for the growing season of 2020 and 2021, they included clay-loam, slightly alkaline (7.7 in two years), unsalted (0.1-0.2%, respectively), moderately calcareous (6.1-2.3%, respectively), low in organic matter (1.6-1.5%, respectively), potassium content above the adequate level (551-421 kg ha^{-1}, respectively), and very little phosphorus (20.8-40.6 kg ha^{-1}, respectively) (Table 2).

Experimental Material

Two different anise populations were used in the study. The seed sample of the first population (P1) was obtained from the city of Izmir, and the seed sample of the second population was obtained from the local producers in the city of Konya. Pure 60 kg ha^{-1} P_2O_5 phosphorus fertilizer (TSP 43-45% P) was given to all plots in planting. Ammonium nitrate (33%) was used as nitrogen fertilizer, and 6 doses of 0 (control), 30, 60, 90, 120, and 150 kg ha^{-1} pure nitrogen were applied. The first half of the nitrogen dosage was administered at the time of sowing, and the second half was applied in the spring.

Table 1. Precipitation temperature, and relative humidity values of experimental years and long-term growing seasons in Kahramanmaras Province (Anonymous 2021a)

Climatic Factory	Year	Months								
		November	December	January	February	March	April	May	June	Total or Avarage
Average Temperature (°C)	2019-2020	13.5	8.4	6.3	6.1	12.5	15.9	15.9	24.5	13.3
	2020-2021	11.4	7.3	6.2	8.3	10.1	16.3	23.2	26.0	13.6
	Long years	11.5	6.8	4.9	6.4	10.6	15.5	20.3	25.3	12.6
Precipitation (mm)	2019-2020	39.1	198	88.0	72.7	173	61.8	18.5	0.3	652
	2020-2021	57.6	62.6	227	32.6	135	16.2	12.0	0	543
	Long years	87.5	117	125	108	93.4	69.8	41.2	8.4	651

Table 2. Some chemical and physical properties of the study area soils (Anonymous 2021b)

Year	Texture class	Organic matter (%)	$CaCO_3$ (%)	EC (dS m^{-1})	pH	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
2020	Clay-loam	1.6	6.1	0.1	7.7	20.8	551
2021	Clay-loam	1.6	2.3	0.2	7.7	40.6	421

Design of the Field Trial and Cultural Practices

The soil was well prepared before the planting. In the experiment, six rows of sowing were used in each plot with a plot length of 3 m, a plot width of 1.8 m, and a distance of 30 cm between rows. On November 21, 2019, for the first year, and on November 19, 2020, for the second, hand-sown seeds were placed in the open 2 to 3-cm-deep scratches with a marker. The RCBD with three replications arranged in the split plots (populations in main plots fertilizer dosages in sub-plots). Following the emergence the standard growing applications were applied by hand when necessary for weed control and irrigation was performed as drip irrigation. Harvesting was performed manually using a reaping hook on 07.07.2020 in the first year and on 05.07.2021 in the second year.

Statistical Analyses

The JMP Pro 13 package application was used to perform statistical analyses to evaluate yield and quality-related parameters in accordance with the split-plot trial design (JMP, 2010). The LSD multiple comparison tests was used to compare the means found to be significant (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

The aim of our research was to determine the effect of increasing nitrogen concentrations on the yield and quality characteristics of anise. Below, two-year data on agronomic, yield and quality-related parameters of nitrogen fertilization in anise plants are explained.

Plant height (cm)

Despite the lack of statistically significant changes in plant height across populations and dosages, it was discovered that years and the population x dosages interaction were both significant at 1% and 5%, respectively (Table 3). The average plant height was 41.9 cm, with a higher value in the first year (51.8 cm) than in the second year (32.2 cm). When evaluated in terms of the population x dose interaction, the highest plant height value was obtained from the 150 kg ha^{-1} nitrogen dose in the Izmir population (43.5 cm), and the lowest plant height from the control dose of the Izmir population (40.7 cm) (Fig 1a). Bayram (1992) reported the plant height values of cultivated anise as 40.1-45.1 cm in Izmir-Bornova ecological conditions; Boztas and Bayram (2021) as 43.0-48.4 cm in anise lines of different origins in Izmir ecological conditions; Arslan et al. (1999) reported plant height as 44.2-58.9 cm in anise in Ankara ecological conditions; Khalid (2013) reported 31.0-44.5 cm plant height in dry conditions in Egypt; Nabizadeh et al. (2012) reported a plant height of 46.6-47.6 cm in the city of Mabahad, Azerbaijan; Plant height was observed to be 43.1-49.3 cm in Eskisehir ecological circumstances by Katar et al. (2021), and 51.1-54.7 cm in Bangalore by Bhuvaneshwari et al. (2002). The plant height values observed in this research were comparable to those found in previous studies and were found to be lower than those found by Bhuvaneshwari et al. (2002). This can be due to demographic variations, the environment in which the plant grows, or different agricultural practices. The genetic makeup of the plant, growth conditions, and agricultural practices all have an effect on the morphological characteristics of anise, such as plant height, according to Acimovic et al. (2014). Numerous past studies have shown that the height of anise plants is not significantly affected by the quantity of fertilizer applied (Nabizadeh et al., 2012; Faravani et al., 2013; Acimovic et al., 2014). Poudel et al. (2018) reported that the increase in the amount of nitrogen positively affects plant height, and this may be due to the role of nitrogen in cell division, cell growth and protein synthesis.

Total number of branches (number plant^{-1})

When the effects of various nitrogen dosages on the total number of branches in anise were examined, the year and dosage were significant at the 1% level, the population at the 5% level, and the population x dose interaction was statistically insignificant. The Izmir population (12.0 number plant^{-1}) had more branches than the Konya population (11.4 number plant^{-1}) had (Table 3). Parallel to the higher nitrogen dosages, a rise in the number of branches was seen. With 13.5 number plant^{-1} and 150 kg ha^{-1} N, the most branches were produced, while with 10.3 number plant^{-1} and the control dosage (0 kg ha^{-1} N), the least. In terms of years, the first year (18.8 number plants^{-1}) had a greater value for the number of branches than the second year (4.5 number plants^{-1}). The second year of the research was hotter and drier, which had an impact on how plants developed (Table 1). Arslan et al. (1999) sated that the number of branches as 5.2-8.3, Boztas and Bayram (2021) reported 6.2-8.8 number plants^{-1}, Bhuvaneshwari et al. (2002) reported 27.2-30.6 pieces, Khalid (2013) as 4.6-8.5 pieces, Nabizadeh et al. (2012) as 8.9-9.3 pieces, and Sonmez (2018) reported as 6.5-6.8 piece. The total number of branches in this study were discovered to be comparable to those reported by Arslan et al. (1999), Boztas and Bayram (2021), Khalid (2013), and Nabizadeh et al. (2012), but less than those reported by Bhuvaneshwari et al. (2002), more than those reported by Sonmez (2018), and close to those reported by Arslan et al. (1999). According to several studies, the reasons for these variations include the population utilized, the environment where the crops were produced, and different agricultural techniques. Nitrogen is a vital nutrient that, with rising nitrogen doses, improves vegetative components and boosts the number of branches, according to Izgi (2020). The fertilizer doses of 60 kg ha^{-1} N and 0 kg ha^{-1} P together resulted in a 9.6% larger total branch number than the control, according to Bayram (1992), who also found that nitrogen fertilization promoted branching in the plant. Ayub et al. (2011) stated that nitrogen application may increase the root and shoot development of the plant, causing the number of umbels in the plant to increase. It has been reported by Sultana et al. (2019), that regular application of nitrogen can contribute to the increase in the number of branches by increasing the branching ability of vegetative buds and vegetative branch production.

Number of branches with fruit (number plant^{-1})

When the effects of various nitrogen levels on the number of fruiting branches in anise were investigated, the year and dosage were significant at the 1% level, the population x dose interaction was significant at the 5% level, and the difference between populations was not significant. The application of 150 kg ha^{-1} nitrogen produced the most fruiting branches (5.3 number of plants^{-1}), while the doses of 0, 30, and 90 kg ha^{-1} nitrogen produced the fewest fruiting branches (both of which were statistically in the same group). It was discovered that there were more fruiting branches in the first year (6.5 number plants^{-1}), compared to the second year (3.4 number plants^{-1}) (Table 3). When the population x dosage interaction was assessed, the Izmir population received a dose of 150 kg ha^{-1} N, which produced the maximum number of fruit branches, and a dose of 30 kg ha^{-1} N, which produced the lowest number of fruit branches (Fig 1b). In their studies on the number of fruiting branches, Boztas and Bayram (2021) reported 4.7-7.2 pieces plant^{-1}, while Arslan et al. (1999) reported 3.0-5.2, both of which are compatible with the results of the present research. Bayram (1992) observed that the highest nitrogen dose 60 kg ha^{-1} N and 0 kg ha^{-1} P produced the most fruiting branches when considering the fertilizer doses. Higher nitrogen concentrations promote vegetative development and branch formation, according to Tuncturk (2008).

Table 3. Two-year averages and LSD groupings of applied nitrogen doses on yield and vegetative properties in anise

		PH	NTB	NFB	NU	SY	TSW
Population (P)	P_1 (Izmir)	42.0	12.0 a	5.0	9.8 a	349 b	2.7 b
	P_2 (Konya)	41.9	11.4 b	4.9	8.2 b	410 a	3.4 a
Doses (N kg ha^{-1})	0 (Control)	41.7	10.6 d	4.9 c	8.1 c	351 d	2.8 d
	30	41.7	11.0 cd	4.8 c	9.1 ab	362 cd	2.9 cd
	60	41.8	11.9 ab	5.1 ab	8.9 b	376 bc	3.0 b
	90	42.1	12.4 ab	4.9 c	9.6 a	390 ab	3.1 b
	120	42.0	11.7 bc	4.9 bc	9.2 ab	399 a	3.0 bc
	150	42.7	12.5 a	5.3 a	9.3 ab	400 a	3.5 a
Year	2020	51.8 a	18.8 a	6.5 a	14.0 a	505 a	3.0
	2021	32.2 b	4.5 b	3.4 b	4.1 b	255 b	3.0
Population x Doses (P x D)	P_1 x D_0	40.7 c	10.9	4.8 cde	8.9 cde	332 de	2.5 g
	P_1 x D_{30}	41.6 abc	11.0	4.3 f	9.5 cd	322 g	2.5 fg
	P_1 x D_{60}	42.1 abc	11.7	5.0 bcd	9.3 cde	339 fg	2.7 efg
	P_1 x D_{90}	41.2 bc	12.8	4.7 ef	10.6 ab	377 d	2.7 ef
	P_1 x D_{120}	42.7 ab	12.0	4.8 cde	9.7 bc	371 de	2.8 e
	P_1 x D_{150}	43.5 a	13.5	5.9 a	11.0 a	354 ef	2.8 de
	P_2 x D_0	42.7 ab	10.3	4.9 b-e	7.4 g	370 de	3.1 cd
	P_2 x D_{30}	41.8 abc	11.1	5.2 b	8.6 de	402 c	3.2 bc
	P_2 x D_{60}	41.6 abc	12.0	5.3 b	8.5 ef	413 bc	3.4 b
	P_2 x D_{90}	43.0 ab	12.0	5.1 bc	8.6 de	403 c	3.4 b
	P_2 x D_{120}	41.4 bc	11.4	5.0 bc	8.6 de	428 ab	3.2 bc
	P_2 x D_{150}	42.0 abc	11.4	4.7 de	7.6 fg	447 a	4.1 a
Mean		41.9	11.7	5.0	9.0	380	3.1
CV		4.5	8.0	6.0	9.0	5	6.6
LSD for year		0.9**	0.4**	0.2**	0.4**	9**	-
LSD for population		-	0.4*	-	0.4**	9**	0.1*
LSD for doses		-	0.8**	0.3**	0.7**	16**	0.2**
LSD for P x D interaction		2.2*	-	0.4*	0.9*	23**	0.2**

PH: Plant height (cm), NTB: Number of total branches (Branch plant^{-1}), NFB: Number of fruit branches (Fruity branch plant^{-1}), NU: Number of umbels (Umbels plant^{-1}), SY: Seed yield (kg ha^{-1}), TSW: Thousand seeds weight (g)

Number of umbrellas (number plant^{-1})

Anise populations growing at different nitrogen doses were significant at the 1% level in terms of the quantity of umbrellas, years, dosages, and populations, while the population x dose interaction was significant at the 5% level. The Izmir population (9.8) had more umbrellas than the Konya population (8.2), with an average of 9.0 umbrellas per person. In terms of dosages, the dose of 90 kg ha^{-1} N produced the greatest umbrella number value, while the dose of 0 kg ha^{-1} N produced the lowest. In terms of years, there were more umbrellas in the first year (14.0) than the second year (4.1) (Table 3). According to figure 1c, the highest number of umbrellas was obtained from the dose of 150 kg ha^{-1} N in the Izmir population, and the lowest number of umbrellas was obtained from the dose of 0 kg ha^{-1} N in the Konya population. Faravani et al. (2013) reported the number of umbrellas in the range of 9.4- 11.4 pieces, Bhuvaneshwari et al. (2002) 33.7-51.7, Khalid (2013) 12.0-29.7, Sonmez (2018) 7.5-7.8, Kara (2015) reported the highest number of umbrellas as 10.1 in the first year and 10.6 in the second year. Similarly, there was a difference between the years regarding the number of umbrellas in this study. The reason for this was climatic differences, e.g., precipitation and temperature, between years (Table 1). The number of umbrellas was less than that recorded by Bhuvaneshwari et al. (2002) and Khalid (2013), but more than that of Kara (2015), Faravani et al. (2013), and Sonmez (2018). This might be due to different soil types, local weather patterns, irrigation, cultivation techniques, genotypes, and nitrogen doses (Ehsanipour et al., 2012). Nitrogen treatments may stimulate the plant to develop its roots and shoots more rapidly and generate more umbrella-shaped leaves, according to Ayub et al. (2011). When nitrogen doses were increased in the fennel plant, more umbrellas and branches appeared, according to Tuncturk (2008).

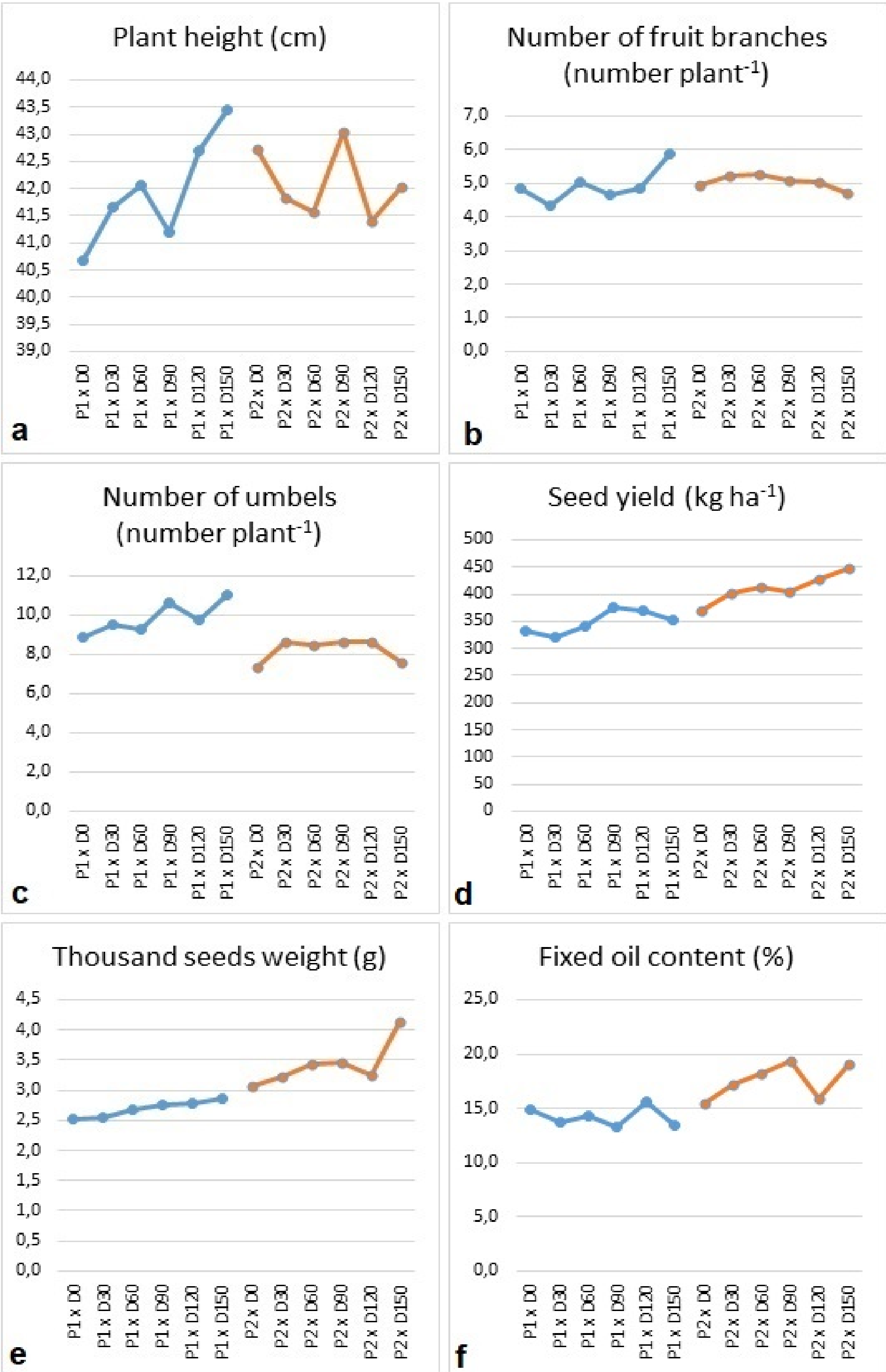

Figure 1. Two-year average values of genotype × dose interaction, which is statistically significant in the investigated characteristics (a-f)

Seed yield (kg ha^{-1})

When the effects of different nitrogen dosages on anise seed production were analyzed, the interaction of population, year, dosage, and population x dose was significant at the 1% level. The average seed production was 380 kg ha^{-1}, with the Konya population producing more seeds (410 kg ha^{-1}) than the Izmir population (349 kg ha^{-1}). The best seed yield was obtained with doses of 120 and 150 kg ha^{-1} N from the same group. In respect of dosages, the control treatment resulted in the lowest seed yield (0 kg ha^{-1} N). The yield of seeds in the first year was much higher than in the second (Table 3). When the population x dosage interaction was assessed, the Konya population produced the maximum seed yield at a dose of 150 kg ha^{-1} N, whereas the Izmir population produced the lowest seed yield at a dose of 30 kg ha^{-1} N. (Table 3; Fig 1d). The seed yield was reported to range from 501 to 691 kg ha^{-1} by Boztas and Bayram (2021), 319 to 404 kg ha^{-1} by Faravani et al. (2013), 560 to 889 kg ha^{-1} by Arslan et al. (1999), and 1371 to 1912 kg ha^{-1} in the first year and 1293 to 1566 kg ha^{-1} in the second year by Acimovic et al. (2014). The range was reported as 561-801 kg ha^{-1} by Katar et al. (2021), 739-768 kg ha^{-1} by Sonmez (2018), and 453 kg ha^{-1} and 550 kg ha^{-1}, accordingly, by Kara (2015) for the highest seed yield. Our results indicated that even while our values were similar to those found by Kara (2015), Faravani et al. (2013), Bhuvaneshwari et al. (2002), and Bayram (1992), they were lower than those reported for seed yield by Boztas and Bayram (2021), Arslan et al. (1999), Acimovic et al. (2014), Katar et al. (2021), and Sonmez (2018). These differences between studies may result from the population, cultivation in different ecological regions and agricultural activities applied. Bayram (1992) achieved the maximum grain output of 481 kg ha^{-1} in comparison to the control using a fertilizer mixture of 30 kg ha^{-1} N and 60 kg ha^{-1} P. According to Bhuvaneshwari et al. (2002) the seed yield ranged from 189 to 698 kg ha^{-1}, and increasing nitrogen treatments had a massive effect on yield parameters such as umbrella number, umbrella number, and seed yield. Dordas and Sioulas (2008) reported that the increase in seed yield with N application may be a result of the N effect on photosynthesis, dry matter division, and the amount of assimilate produced by the plant.

Thousand seed weight (g)

When the effects of increasing nitrogen treatments on anise's 1000 seed weight were evaluated, the populations, dosage, and population x dose interaction were all significant at the 1% level and there was no seasonal change. The average weight of a thousand seeds was determined to be 3.1 g, with Konya's population having a greater average weight (3.4 g) than Izmir's population (2.7 g). The evaluation of the dosages revealed that raising the nitrogen doses had a favorable impact on thousand seed weight. The application of 150 kg ha^{-1} N produced the greatest thousand-seed weight and 0 kg ha^{-1} N produced the lowest. Looking at Figure 1e, it can be seen that the highest thousand seed weight was produced in the Konya population with 150 kg ha^{-1} N application, while the lowest thousand seed weight was obtained with 0 kg ha^{-1} N application in the Izmir population. (Table 3). The weight of a thousand seeds was reported as 3.0–3.9 g by Faravani et al. (2013), 2.3-3.1 g by Boztas and Bayram (2021), 3.8-4.0 g by Katar et al. (2021), 2.8-3.3 g by Sonmez (2018), and 3.5-3.5 g by Kara (2015). The thousand-grain weight in this analysis was consistent with the figures in related studies. According to Bayram (1992), application of nitrogen and phosphorus fertilizers increased the weight of 1000 grains. According to Tuncturk (2008), there may be a significant variation in thousand-seed weights due to a variety of variables, including population diversity, growing environments, and various farming techniques. Additionally, higher dry matter buildup and thousand seed weight in seeds were observed under ideal soil and development conditions.

Protein content (%)

The interaction of population, year, dosage, and population x dose was significant at the 1% level when measured in terms of the impact of various nitrogen doses on the protein content in anise. More protein was present in the Konya population (17.4%) than in the Izmir population (15.2%). The 150 kg ha^{-1} N treatment yielded the greatest protein content (17.8%), while the control application yielded the lowest value (15.3%) when nitrogen dosages were considered (Table 4). In the first year of the research (17.4%), the protein content was greater than in the second year (15.1%). In terms of the population x dosage interaction, the Konya population's 150 kg ha^{-1} N application had the greatest protein content (20.2%) while the Izmir population's control application of 0 kg ha^{-1} N had the lowest protein content (14.1%) (Fig 2j). According to Khalid (2013), the protein content was between 14.1 to 16.8%, which agrees with the results of this investigation. According to Khalid (2013), nitrogen supplied to the soil had a favorable impact on anise's protein content, with 200 kg ha^{-1} N treatment yielding the maximum protein level. He also said that the impact of nitrogen on the ribosome structure and the production of various hormones (cytokines, auxins, and gibberellins) involved in protein synthesis may be the cause of this (Jones et al., 1991). Nitrate, especially applied in sufficient amounts, is essential for metabolism, especially for the assimilation of amino acids and their availability in protein synthesis (Lawlor, 2002). According to Yasari and Patwardhan (2006), nitrogen fertilization increased the protein content of the seeds, the reason for this is the increase in the rate or conversion of carbohydrates into protein and the increase in the rate or N uptake, which leads to higher protein synthesis by the plant.

Fixed oil content (%)

In terms of constant oil content, the interaction of population, year, dosage, and population x dose was significant at the 1% level. The population of Konya (17.5%) had a higher fixed oil content than the population of Izmir (14.2%), and the average fixed oil content was 15.8%. As nitrogen doses were raised, anise's fixed oil prices climbed. The highest fixed oil content was generated by the same group's applications of 60, 90 and 150 kg ha^{-1} N dose, whereas the lowest fixed oil content was produced by the control treatment (0 kg ha^{-1} N). In the second year of the study (16.7%), a lower fixed oil content was attained than in the first (15.1%). Figure 1f demonstrates that Izmir's population got the lowest fixed oil content (90 kg ha^{-1} N application), whereas Konya's population received the highest (90 kg ha^{-1} N application) (Table 4). According to Khalid (2013), nitrogen fertilizer enhanced the quantity of fixed oil in the fruits of anise, coriander, and sweet fennel, with the fixed oil rate in anise rising by 8.1% in contrast to the control. Studies have shown that extensive nitrogen fertilizer boosted the production of anise's fixed oil; the maximum rate of fixed oil production was achieved with a dosage of 200 kg ha^{-1} N (Khalid, 2013).

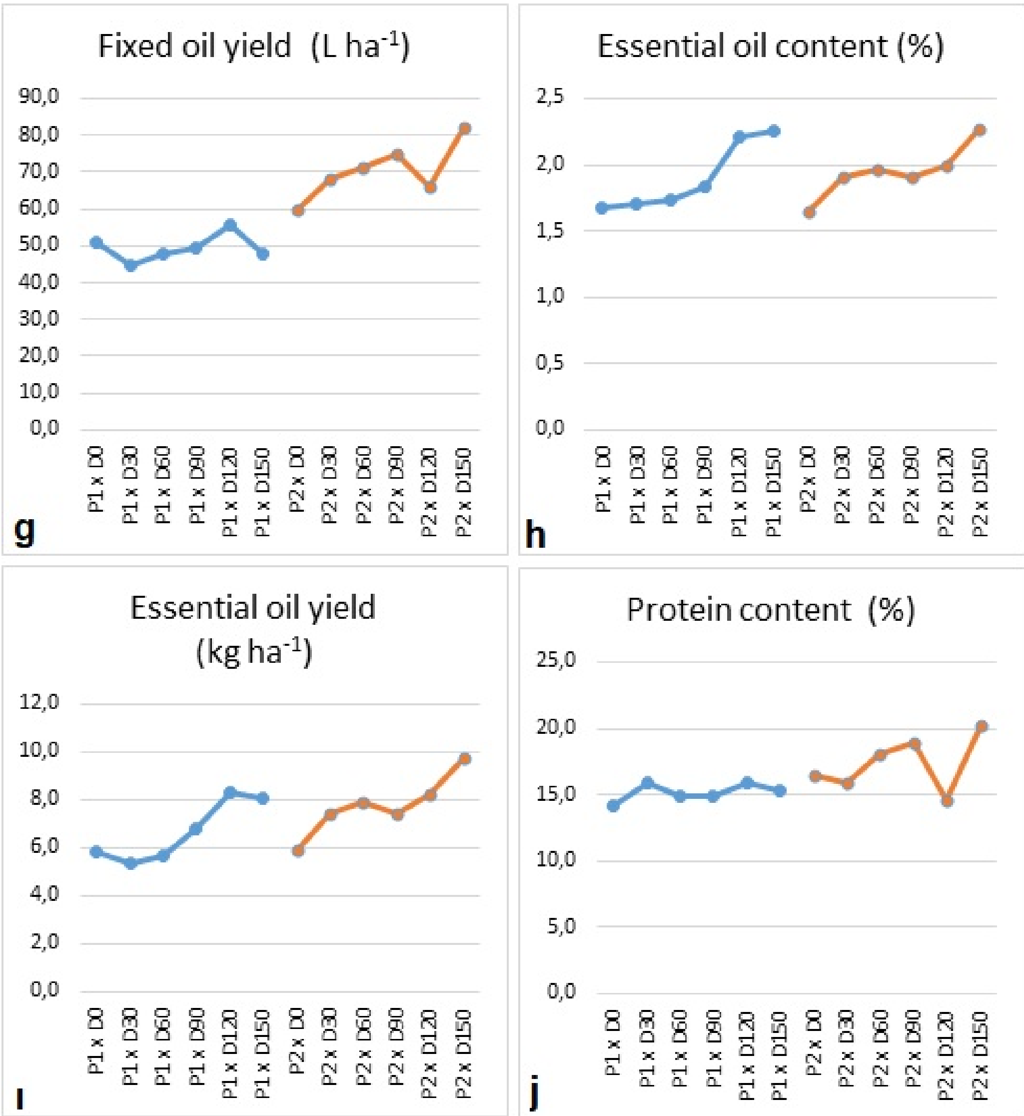

Figure 2. Two-year average values of genotype × dose interaction, which is statistically significant in the investigated characteristics (g-j)

Fixed oil yield (kg ha^{-1})

The fixed oil production in anise cultivated at various nitrogen doses was significantly influenced by the population, dosage, year, and population x dose interaction at the 1% level. In terms of fixed oil yield, the Konya population (70.4) was greater than the Izmir population (49.4). The lowest fixed oil yield was achieved in the control (55.2) and 30 kg ha^{-1} N (56.4) doses, which were statistically in the same group, while the maximum fixed oil yield was obtained in the 150 kg ha^{-1} N dosage (64.9). The first year (76.6) had a better value than the second year in terms of fixed oil yield (43.2). When assessed in terms of the population x dosage interaction, the Konya population received a 150 kg ha^{-1} N treatment, while the Izmir population received a 30 kg ha^{-1} N application, yielding the greatest fixed oil value (Table 4; Fig 2g). Since seed yield and oil rate were used to determine fixed oil yield, it fluctuated based on these numbers. Nitrogen applications generally increase the oil content and yield in aromatic plants by increasing the amount of biomass yield per unit area, leaf area development and photosynthetic rate (Ram et al., 1995).

Essential oil content (%)

According to data in (Table 4), there was no difference in the populations, but the dosage and population x dose interaction were found to be significant at the 1% level for essential oil contents. The essential oil concentration was highest (2.3%) in the 150 kg ha^{-1} N treatment and lowest (0 kg ha^{-1} N) in the control application. The first year's essential oil content (1.8%) was lower than the second year's (2.0%). In terms of the population x dosage interaction, the greatest essential oil content was found in the populations of Konya and Izmir at doses of 150 kg ha^{-1} N and 120 kg ha^{-1} N, respectively, which were statistically in the same group. In both populations, the lowest essential oil content value was found during control applications (0 kg ha^{-1} N) (Table 4; Fig 2h). When the research period was drier in the second year, the essential oil content had a greater value. The essential oil content in cumin fruits was similarly reported by Acimovic et al. (2015) as 4.1% in the second year of the dry and hot trial and 3.8% in the first year of the cool year. It has been claimed that anise's essential oil composition is considerably influenced by the weather throughout the growth season. The quantity and makeup of essential oils are genetically documented, but they also function well under climatic settings throughout the stages of fruit creation and ripening (Sedlakova et al., 2003). The essential oil content was recorded as 1.8%-2.6% by Boztas and Bayram (2021), 3.8-4.1% by Faravani et al. (2013), 1.3%-1.9% by Dogramaci and Arabaci (2015), 1.3-3.7% by Arslan et al. (2004), 2.6-3.2% by Khalid (2013), 2.7-2.9% by Katar et al. (2021), 2.5-3.1% by Satibese et al. (1994). This study's essential oil content was lower than that of Faravani et al. (2013), Khalid (2013), Satibese et al. (1994), and Sonmez (2018), and it was consistent with the results of the previous studies stated above. When compared to control, all nitrogen amounts added to the soil resulted in a steady rise in the essential oils produced by anise, coriander, and sweet fennel plants (Khalid, 2013). According to Khalid (2014), the primary component (trans-anethole) rate rose when compared to the control, but varied nitrogen dosages did not affect the number of essential oil components. The maximum essential oil rate was found to be 3.2% at a dose of 200 kg ha^{-1} N. Additionally, it was said that the beneficial benefits of nitrogen fertilization may be attributable to nitrogen's significant physiological functions in the molecular structure, such as porphyrin (Khalid, 2013).

Table 4. Two-year averages and LSD groupings of applied nitrogen doses for properties examined in anise

		PO	FOR	FOY	EOR	EOY
Population (P)	P_1 (Izmir)	15.2 b	14.2 b	49.4 b	1.9	6.7 b
	P_2 (Konya)	17.4 a	17.5 a	70.4 a	1.9	7.8 a
Doses (N kg ha^{-1})	0 (Control)	15.3 e	15.1 c	55.2 c	1.7 d	5.8 e
	30	15.9 d	15.4 bc	56.4 c	1.8 c	6.4 d
	60	16.5 c	16.3 a	59.6 b	1.8 c	6.8 c
	90	16.9 b	16.3 a	62.2 ab	1.9 c	7.1 c
	120	15.2 e	15.8 ab	60.9 b	2.1 b	8.3 b
	150	17.8 a	16.3 a	64.9 a	2.3 a	8.9 a
Year	2020	17.4 a	15.1 b	76.6 a	1.8 b	9.2 a
	2021	15.1 b	16.7 a	43.2 b	2.0 a	5.3 b
Population x Doses (P x D)	P_1 x D_0	14.1 ı	14.9 ef	50.7 g	1.7 e	5.8 ef
	P_1 x D_{30}	15.8 e	13.7 gh	44.6 h	1.7 de	5.3 f
	P_1 x D_{60}	14.9 g	14.3 fg	48.1 gh	1.7 de	5.7 ef
	P_1 x D_{90}	14.9 g	13.3 h	49.4 g	1.8 cd	6.8 d
	P_1 x D_{120}	15.8 e	15.6 de	55.6 f	2.2 a	8.3 b
	P_1 x D_{150}	15.3 f	13.5 gh	47.7 gh	2.2 a	8.1 b
	P_2 x D_0	16.5 d	15.4 de	59.7 e	1.6 e	5.9 e
	P_2 x D_{30}	15.9 e	17.1 c	68.3 cd	1.9 bc	7.4 c
	P_2 x D_{60}	18.1 c	18.3 b	71.1 bc	2.0 b	7.9 bc
	P_2 x D_{90}	18.9 b	19.3 a	75.1 b	1.9 bc	7.4 c
	P_2 x D_{120}	14.6 h	15.9 d	66.2 d	2.0 b	8.3 b
	P_2 x D_{150}	20.2 a	19.0 ab	82.1 a	2.3 a	9.8 a
Mean		16.3	15.8	59.8	1.9	7.2
CV		0.1	4.5	5.7	5.4	5.9
LSD for year		0.1**	0.3**	1.6**	0.1**	0.2**
LSD for population		0.1**	0.3**	1.6**	-	0.2**
LSD for doses		0.1**	0.6**	2.8**	0.1**	0.3**
LSD for P x D interaction		0.2**	0.8**	4.0**	0.1**	0.5**

PO: Protein ratio (%), FOR: Fixed oil ratio (%), FOY: Fixed oil yield (kg ha^{-1}), EOR: Essential oil ratio (%), EOY: Essential oil yield (L ha^{-1})

Essential oil yield (L ha^{-1})

At the 1% level, the interaction of population, year, dosage, and population x dose was significant for essential oil output. The Konya population had a greater essential oil production (7.8 L ha^{-1}) than the Izmir population (6.7 L ha^{-1}) and the average essential oil yield was 7.2 L ha^{-1}. In terms of dosages, the 150 kg ha^{-1} N application produced the maximum essential oil output, whereas the control group produced the lowest value (0 kg ha^{-1} N). The first year (9.2 L ha^{-1}) had a larger essential oil output than the second year in terms of years (5.3 L ha^{-1}). In terms of the population x dosage interaction, the Konya population received a 150 kg ha^{-1} N dose, whereas the Izmir population received 30 kg ha^{-1} N application, yielding the maximum essential oil output (Table 4; Fig 2ı). Essential oil yield was determined to be 12.0-14.9 kg ha^{-1} by Faravani et al. (2013), 377-1675 L ha^{-1} by Dogramaci and Arabaci (2015), 52.2-76.8 L ha^{-1} in the first year and 44.9-57.9 L ha^{-1} in the second year by Acimovic et al. (2014), 7.3-14.0 kg ha^{-1} by Bhuvaneshwari et al. (2002), 1.5-2.0. According to Bhuvaneshwari et al. (2002), the application of 80 kg ha^{-1} N, the highest dosage, resulted in the greatest essential oil output (14.0 kg ha^{-1}). According to Bayram (1992), varied sowing techniques and fertilizer applications have an impact on the output of essential oils. The combination of fertilizer applications of 30 kg ha^{-1} N and 60 kg ha^{-1} produced an essential oil yield that was 21.1% greater than the control. Ehsanipoura et al. (2012) reported that differences between seed essential oil content, seed essential oil yield, protein and leaf essential oil content, could be due to genetic differences between the varietys and their response to N fertilization, and growing conditions of the experimental site.

CONCLUSION

One of the economically significant medicinal and aromatic herbs is anise. Nitrogen fertilizer treatments had a substantial influence on all of the evaluated parameters in the present research, which assessed the impacts of different nitrogen dosages on yield and quality characteristics, with the exception of plant height. The only difference between Konya and Izmir's populations was the overall number of branches and umbrellas. Increasing nitrogen doses showed significant increases in the number of fruiting branches and the number of umbrellas, which are among the plant characteristics. Thousand seed weight, which is important in terms of yield and quality, was significantly affected by increasing nitrogen doses. Essential oil ratio and essential oil yield, which are quality characteristics, were affected by nitrogen doses and had the highest value at the highest dose applied. In terms of seed yield, the Konya population has a higher value than the Izmir population, and increased nitrogen doses affected seed yield positively.

According to the results of the study, it is seen that it would be appropriate to use Konya as a population and 120 kg ha^{-1} N as a fertilizer dose.

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