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Effect of Different Nitrogen Doses on Quality Characteristics of Sater (*Satureja hortensis* L.) Plant

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Abstract

Satureja hortensis is an important species among the medicinal and aromatic plants used as thyme. This study was carried out in Kahramanmaras central conditions in order to determine the yield and quality characteristics of *Satureja hortensis* (0, 5, 10, 15, 20, 25, 30, 35, 40, 45 kg da^{-1}) at increasing nitrogen doses. The experiment was set up in the research area of Sutcu Imam University, Faculty of Agriculture, Department of Field Crops according to the Factorial experimental design in randomized blocks with 3 replications. According to the results of essential oil analysis and macro-micro nutrients; essential oil yield was determined as 5.19-20.79 L da^{-1}, protein ratio was determined as 11.12-22.70%. Twenty-three different components were determined in the essential oil and the main components are; carvacrol was determined as 31.64-39.03%, ɣ-terpinene as 32.38-38.27%, p-cymene as 6.34-10.71%, carene as 2.90-5.60% and myrcene as 3.06-3.91%. Plant nutrients in dry herba; phosphorus was determined in the range of 2361.00-4552.00 mg kg^{-1}, iron 107.45-222.85 mg kg^{-1}, zinc 25.18-47.82 mg kg^{-1}, manganese 22.16-46.92 mg kg^{-1}, potassium 12790.00-22615.00 mg kg^{-1}, calcium 10225.00-21235.00 mg kg^{-1}, copper 9.15-17.73 mg kg^{-1}, sodium 33.41-75.55 mg kg^{-1} and nitrogen was determined in the range of 2.21-4.50%.

Key words
Sater, Satureja hortensis, Essential oil, Nitrogen doses.

Introduction

The use of medicinal and aromatic plants has a very long history in the world. According to the World Health Organization (WHO), there are 20,000 plant species for medicinal purposes, 4,000 of which are widely used, while 10% have commercial value (Satıl et al. 2008). Turkey is among the leading countries in the production and export of thyme, both cultivated and collected from natural growth areas. Thyme, which has an important place among medicinal and aromatic plants, is a very important plant in terms of its contribution to both the local people who produce it and the country's economy (Anonymous, 2020). Many plant species containing "carvacrol" and "thymol" in their essential oils are considered "thyme" (Tasar et al. 2023). Thyme is the first plant that comes to mind when it comes to spice trade in Turkey. Plant species belonging to different genera (*Origanum, Thymus, Thymbra, Satureja*) are evaluated as thyme in Turkey, and the brand value of "Turkish thyme" has been accepted internationally (Anonymous, 2020). While some thyme species are collected from nature, some are cultivated. Some of the thyme species exported as thyme are *Satureja species* (Satıl et al. 2004). While there are 50 species of the *Satureja* genus in the world (Davis, 1982), it is represented by 16 species in Turkey (Dirmenci et al., 2019). *Satureja hortensis*; mediterranean origin, annual, herbaceous, varying between 10 cm and 30 cm in height, with white-pink-purple flowers, is cultivated by seed in Mediterranean climates and temperate climates. In addition to its many uses, the leaves of the plant are used as a spice. The leaves are 1-3 cm long, spear-oval shaped, stemless, hairy, gray green-brown. Its scent is thyme-like, spicy, herbaceous, and its taste is bitter, spicy, sharp and astringent. In 100 g of spice; It contains 272 kcal energy, 9 g water, 6.7 g protein, 5.9 g fat, 68.7 g carbohydrate, 15.3 g fiber, 9.6 g ash, 22132 mg Ca, 38 mg Fe, 377 mg Mn, 140 g P, 1051 mg K, 24 mg Na, 4 mg Zn (Akgül, 1993). The oil is close to yellow-brown in color with a yield of 0.5-1.5 % by steam distillation from the whole flowering plant of *Satureja hortensis*. Although the main component in the volatile oil is generally carvacrol, thymol, p-cymene, ɣ-terpinen, borneol or linalool can also be the main components in some chemotypes (Akgül, 1993). The essential oil of the sater plant has an important place among medicinal plants because it is used in cosmetics, medicine, food and many other industrial areas (Makkizadeh et al. 2012). It has been reported that *Satureja hortensis* essential oil has strong antibacterial activity against *Proteus vulgaris*, *Bacillus subtilis*, *Klebsiella pneumoniae* and *Escherichia coli* (Ilic et al. 2023). This study was carried out to determine how increasing nitrogen applications affect the essential oil yield, protein content, plant nutrient element content and essential oil components in sater plant.

Material and Method

The seed material of the *S. hortensis* species used in the study was obtained from people who grow it in the Nurhak district of Kahramanmaras province. The seeds were planted in the greenhouse on 25 March 2022, and the seedlings that reached 5 cm in length were transplanted into the viols prepared with a mixture of peat and sand, and the thyme seedlings were kept in a semi-shaded environment until the appropriate planting time so that they could get used to the external environmental conditions. After the soil preparation of the trial area was done, the trial was set up with a seedling planting machine on 12 May 2022, taking into account a distance of 40 x 25 cm in 5 rows. After the seedlings were transplanted to the trial area, a drip irrigation system was established and the plants were watered regularly. Weeds were physically weeding, and no disease agents were encountered until the cutting time of the plant. In the trial area, TSP (triple super phosphate) (42%) was used as phosphorus and ammonium nitrate fertilizers (33%) were used in the application of nitrogen doses along with planting. Nine different nitrogen doses were applied in the experiment: 0 (control), 5, 10, 15, 20, 25, 30, 35, 40 and 45 kg da^{-1}. As a base fertilizer, all phosphorus (6 kg da^{-1}) and half of the nitrogen doses were given at planting, while the remaining half of the nitrogen was given when the plants reached 10-15 cm in height.

Climate and soil characteristics of the trial area:

The climate data for the March-October 2022 growing season, when the study was carried out, are given in Table 1.

Table 1. Kahramanmaras province 2022 climate data (Anonymous, 2024)

Months	Precipitation (mm)		Average Temperature (°C)	
	2022	Long years (1980-2022)	2022	Long years (1980-2022)
March	157.8	95.10	7.14	10.40
April	12.7	73.00	18.24	15.10
May	40.4	38.80	20.38	20.10
June	3.7	8.60	26.16	24.90
July	0.5	2.70	29.61	28.30
August	0	2.20	29.37	28.40
September	10.7	11.00	26.09	25.00
October	12.3	45.40	20.60	18.90
Total or Average	238.1	276.8	22.20	21.39

The total rainfall amount of 2022 (238.1 mm) is below the total rainfall amount of long years (276.8 mm). While the average temperature between March and October of 2022, when the study was carried out, was 22.20 ºC, the long-term average temperature of Kahramanmaras was 21.39 ºC. In Kahramanmaras conditions, 2022 had a temperature value above the long-term average temperature (Table 1). When the soil properties taken from the 0-30 cm depth from the experimental area were examined, it was determined that it was clayey loamy (water saturation 60%), slightly alkaline (pH 7.58), low in organic matter (1.16%), low in lime (0.93%), salt-free in terms of salinity (0.01%) and low in phosphorus (4.73 kg da^{-1}).

Examined Features: Essential oil yield (L da-1): Calculated by dividing the essential oil ratios obtained from the study by the herb yield per decare and stated as L da-1.

Essential Oil Components (%): The components and percentages of the essential oils obtained by steam distillation from dry herb were determined by analyzing them on the GS-MS device. Component analysis was carried out by receiving service from Cukurova University Central Research Laboratory (CUMERLAB).

GS-MS Analysis Conditions: Volatile component analysis was determined with Agilent Brand 7890B GC, 7010B MS system. In the analysis, 1 uL of sample was injected into DB-Wax (60 m x 0.25mm i.dx 0.25 μm, J&W Scientific-Folsom, USA) capillary column through a 0.45 um filter. Injection temperature was 250 °C, column temperature was increased by 3 °C per minute to 90 °C after waiting for 4 minutes at 40 °C, then by increasing it by 4 °C per minute to 130 °C, and after waiting for 4 minutes at this temperature, the temperature was adjusted to 240 °C by increasing it by 5 °C per minute and kept at this temperature for 8 minutes. He was used as the carrier gas. Electron energy was 70 eV and mass range was 30-600 m/z. Split was 1:20. NIST14L was used as the library.

Macro-Micro Nutrient Elements: The ratios of N, P, K, Ca, Fe, Mn, Cu, Zn and Na nutrients in the material obtained from the dry herbs of the Sater plant and ground were determined. The determination of plant nutrients was carried out by receiving service from KSU USKIM Laboratory.

Crude protein ratio (%): Nitrogen ratios of dry herb samples were calculated with the Micro Kjeldahl method and crude protein ratios were obtained by multiplying with the coefficient of 6.25.

Evaluation of data: The analysis results of the quality-related characteristics obtained from the conducted study were performed using the SAS 9.1 package program for analysis of variance according to the factorial experimental design in randomized blocks. Significant differences were subjected to the LSD multiple comparison test (P<0.05 according to the significant probability limit).

Result and Discussion

Essential oil yield and Crude protein ratio

In terms of the effect of increasing nitrogen doses on essential oil yield in sater plants, cutting, dose and cutting x dose interaction were found to be statistically significant at 1% (Table 2).

Table 2**.** Data on the effect of increasing nitrogen doses on the essential oil yield and crude protein content of sater plant.

Doses	**Essential oil yield (L da^{-1})**			**Protein content (%)**		
(kg da^{-1} N)	**Cutting 1**	**Cutting 2**	**Total**	**Cutting 1**	**Cutting 2**	**Mean**
0	9.24 d	8.47 d	17.72 E	16.37 l	13.83 q	15.10 H
5	6.69 f	6.57 fg	13.25 F	16.12 m	15.47 n	15.80 G
10	13.41 c	5.19 g	18.60 E	18.35 j	15.54 n	16.95 F
15	15.64 b	8.39 ed	24.03 CD	24.78 c	14.28 p	19.53 C
20	16.19 b	6.37 fg	22.57 D	20.14 g	16.43 l	18.29 E
25	16.99 b	6.66 f	23.66 CD	22.08 f	17.38 k	19.73 C
30	19.94 a	9.49 d	29.43A	25.13 b	18.68 ı	21.90 B
35	19.44a	6.15 fg	25.59 BC	22.85 e	15.12 o	18.98 D
40	20.44a	7.08 ef	27.53 AB	23.63 d	15.61 n	19.62 C
45	20.79 a	8.53 d	29.32 A	28.12 a	19.10 h	23.61 A
Mean	15.80 A	7.29 B		21.76 A	16.14 B	
LSD (C)	0.44**			0.12**		
LSD (D)	2.99**			0.27**		
LSD (CxD)	1.39 **			0.21**		

When the effect of applied nitrogen doses on the essential oil yield of sater plant was examined, the average essential oil yield in the first cutting was determined as 15.80 L da^{-1}, and the average essential oil yield in the second cutting was determined as 7.29 L da^{-1}. When the effect of applied doses on essential oil yield was examined, the highest value was statistically obtained from 30 kg da^{-1} (29.43 L da^{-1}) and 45 kg da^{-1} N (29.32 L da^{-1}) applications in the same group, while the lowest essential oil yield was obtained from 5 kg da^{-1} N (13.25 L da^{-1}) application. When the cutting x dose interaction was examined, the highest essential oil yield value was statistically obtained from the first cutting of 30, 35, 40 and 45 kg da^{-1} N doses in the same group, while the lowest value was obtained from 10 kg da^{-1} N application (Table 2). When similar studies were examined; Danalou (2018) obtained the essential oil yield as 2.9-7.11 L da^{-1}, Katar (2015) as 6.27-8.73 L da^{-1}, Katar and Katar (2016) as 5.2-9.4 L da^{-1}, Kaçar et al. (2017) as 2.56-2.87 L da^{-1} and these values are lower than the essential oil values in the study. Katar and Aytac (2019) determined the essential oil yield as 6.54-20.65 L da^{-1} and it is similar to the values obtained in the study. Coban (2019) determined the total essential oil yield in the study conducted in two different locations as 32.93 L da^{-1}-57.04 L da^{-1}, which is higher than the total essential oil yield in this study. In terms of its effect on protein content, cutting, dose and cutting x dose interaction were found to be statistically significant at 1% level. When Table 2 is examined, the average protein content of the first cutting of the application of increasing nitrogen doses (21.76%) is higher than the average protein content of the second cutting (16.14%). When the nitrogen dose averages are examined, the highest protein content was obtained from the 45 kg da^{-1} N application with 23.61%, while the lowest content was obtained from the control application with 15.10%. When the cutting x dose interaction is examined, the highest protein content was obtained from the 45 kg da^{-1} N application (28.12%) of the first cutting, and the lowest protein content was obtained from the control application (13.83%) of the second cutting.

Table 3. Data on β-Myrcene and Carene essential oil components in sater plant with increasing nitrogen doses

Doses	**β-Myrcene (%)**			**Carene (%)**		
(kg da^{-1} N)	**Cutting 1**	**Cutting 2**	**Mean**	**Cutting 1**	**Cutting 2**	**Mean**
0	3.80 bcd	3.73 def	3.76 A	5.50 b	5.28 d	5.39 A
5	3.06 n	3.75 cde	3.40 F	2.90 j	5.41 c	4.15 H
10	3.86 ab	3.57 ıjk	3.71 AB	5.04 fg	5.08 ef	5.06 D
15	3.27 l	3.66 fgh	3.46 E	4.51 ı	5.38 c	4.94 E
20	3.53 jk	3.62 ghı	3.57 D	4.56 ı	5.15 e	4.85 F
25	3.91 a	3.60 hıj	3.75 A	5.60 a	5.00 g	5.30 B
30	3.52 k	3.81 bc	3.66 BC	5.00 g	5.39 c	5.19 C
35	3.18 m	3.32 l	3.25 G	4.58 ı	4.83 h	4.70 G
40	3.61 ghı	3.70 ef	3.65 C	4.76 h	5.28 d	5.02 D
45	3.68 efg	3.33 l	3.50 E	5.11 ef	4.80 h	4.95 E
Mean	3.54 B	3.60 A		4.75 B	5.16 A	
LSD (C)	0.02**			0.02**		
LSD (D)	0.05**			0.05**		
LSD (CxD)	0.07**			0.07**		

As indicated in Table 3, in terms of the effect of increasing nitrogen doses on β-myrcene and carene, which are essential oil components in sater plant, cutting, dose and cutting x dose interaction were found to be statistically significant at 1% level. When the mean values of β-myrcene component were examined, β-myrcene rate in the second cutting (3.60%) was higher than that in the first cutting (3.54%). When β-myrcene rates were examined in terms of applied nitrogen doses, the highest β-myrcene rate was statistically obtained from control (3.76%) application and 25 kg da^{-1} N (3.75%) application in the same group, while the lowest β-myrcene rate was obtained from 35 kg da^{-1} N (3.25%) application. When the cutting x dose interaction was examined, the highest β-myrcene value was obtained from the 25 kg da^{-1} N application of the first cutting with 3.91%, while the lowest β-myrcene value was obtained from the 5 kg da^{-1} N application of the first cutting with 3.06%. When the mean values of the main component of carene were examined, it was seen that the mean carene value of the second cutting (5.16%) was higher than the first cutting carene value (4.75%). When the nitrogen dose means were examined, the highest value was obtained from the control application with 5.39%, and the lowest carene value was obtained from the application of 5 kg da^{-1} N (4.15%). When the cutting x dose interaction was examined, the highest carene value was obtained from the application of 25 kg da^{-1} N (5.60%) of the first cutting, and the lowest value was obtained from the application of 5 kg da^{-1} N (2.90%) of the first cutting (Table 3). In terms of the effect of increasing nitrogen doses on ɣ-terpinene and p-cymene, which are volatile oil components in the sater plant, the cutting, dose and cutting x dose interaction were found to be statistically significant at the level of 1% (Table 4).

Table 4. Data on essential oil components of ɣ-terpinene and p-cymene in sater plant with increasing nitrogen doses

Doses (kg da^{-1} N)	ɣ-terpinene (%)			p-cymene (%)		
	Cutting 1	Cutting 2	Mean	Cutting 1	Cutting 2	Mean
0	37.15 b	35.90 g	36.52 D	9.21 b	8.76 d	8.98 B
5	32.72 k	35.98 f	34.35 I	10.71 a	8.44 ef	9.57 A
10	36.64 e	37.15 b	36.89 C	8.99 c	7.96 ı	8.47 D
15	35.55 ı	37.17 b	36.36 F	7.66 j	7.45 l	7.55 H
20	36.88 c	35.62 ı	36.25 G	8.80 d	8.32 g	8.56 C
25	38.22 a	36.60 e	37.41 A	8.24 h	8.36 g	8.30 E
30	33.93 ı	35.71 h	34.82 H	7.65 j	8.51 e	8.08 F
35	32.38 l	35.88 g	34.13 J	6.34 m	7.93 ı	7.13 I
40	36.83 c	36.75 d	36.79 D	8.79 d	8.39 fg	8.59 C
45	38.27 a	35.89 g	37.08 B	7.54 k	7.91 ı	7.72 G
Mean	35.85 B	36.26 A		8.39 A	8.20 B	
LSD (C)	0.01**			0.02**		
LSD (D)	0.05**			0.05**		
LSD (CxD)	0.07**			0.07**		

When the two cutting periods were examined, it was seen that the ɣ-terpinene rate obtained in the second cutting (%36.26) was higher than the first cutting (%35.85). In terms of doses, the highest ɣ-terpinene value was obtained from 25 kg da^{-1} N application with 37.41%, and the lowest value was obtained from 35 kg da^{-1} N application with 34.13%. When the cutting x dose interaction was examined, the highest ɣ-terpinene value was obtained from 25 kg da^{-1} (38.22%) and 45 kg da^{-1} N (38.27%) applications which are statistically in the same group in the first cutting, while the lowest value was obtained from 35 kg da^{-1} N (%32.38) application of the first cutting (Table 4). When the literature studies were examined; Ceri (2022) found the ɣ-terpinene ratio as 9.47-16.21%, Katar and Aytaç (2019) found the ɣ-terpinene ratio as 28.25-34.88% and Alizadeh et al. (2010) found the ɣ-terpinene ratio as 30.7-40.2%. The ɣ-terpinene ratio in this study is higher than the value of Ceri (2022) and in a similar range to the ɣ-terpinene ratios of Katar and Aytac (2019), and Alizadeh et al. (2010). With increasing nitrogen doses, the p-cymene ratio was determined as 8.39% in the first cutting, while it was determined as 8.20% in the second cutting. When the p-cymene ratios were examined in terms of applied nitrogen doses, it was seen that the highest p-cymene ratio was obtained from 5 kg da^{-1} N (9.57%) application, and the lowest value was obtained from 35 kg da^{-1} N (7.13%) application. When the cutting x dose interaction was examined, the highest p-cymene ratio in sater plant was determined from 5 kg da^{-1} N (10.71%) application of the first cutting, and the lowest value was determined from 35 kg da^{-1} N (6.34%) application of the first cutting (Table 4). Ceri (2022) reported the p-cymene ratio as 9.47-16.21% and gave higher results than the p-cymene ratios in this study, while Alizadeh et al. (2010) reported the p-cymene ratio as 1.8-2.2% in their study, which is lower than the p-cymene ratio of this study.

According to Table 5, in terms of the effect of increasing nitrogen doses on carvacrol, cutting, dose and cutting x dose interaction were found to be significant at the 1% level. When carvacrol rates, one of the important components of Sater essential oil, were examined; carvacrol rate obtained from the second cutting (35.94%) was higher than the carvacrol rate of the first cutting (34.70%). When the average carvacrol rates were examined in terms of doses, the highest was obtained from 15 kg da^{-1} N (37.73%) application, and the lowest carvacrol value was obtained from 30 kg da^{-1} (32.88%) N application.

able 5. Data on carvacrol, one of the essential oil components, in sater plant with increasing nitrogen doses

Doses (kg da^{-1} N)	Carvacrol (%)		
	Cutting 1	Cutting 2	Mean
0	33.41 n	34.27 j	33.84 H
5	34.80 ı	34.02 l	34.41 G
10	33.01 p	36.61 d	34.81 F
15	39.03 a	36.44 e	37.73 A
20	36.06 g	35.74 h	35.90 C
25	33.91 m	36.05 g	34.98 E
30	31.65 q	34.12 k	32.88 I
35	33.17 o	38.54 b	35.85 C
40	35.68 h	35.70 h	35.69 D
45	36.35 f	37.93 c	37.14 B
Mean	34.70 B	35.94 A	
LSD (C)	0.02**		
LSD (D)	0.05**		
LSD (CxD)	0.07**		

When we looked at the cutting x dose interaction, the highest carvacrol value was obtained from 15 kg da^{-1} N (39.03%) application of the first cutting, and the lowest value was obtained from 30 kg da^{-1} N (31.65%) application of the first cutting. Batıray (2009) reported the carvacrol ratio as 46.6-65.2%, Dinç (2014) reported the carvacrol ratio as 39.90-62.36%, Katar and Aytac (2019) reported the carvacrol ratio as 49.65-57.64%, Katar et al. (2011) reported the carvacrol ratio as 55.02-59.94% and Alizadeh et al. (2010) reported the carvacrol ratio as 43.9-59.2% and they obtained higher values than the carvacrol ratio obtained in this study. Ceri (2022) found that the carvacrol ratio varied between 21.67-27.00%. The carvacrol ratio obtained in this study is higher than Ceri (2022). Skubij and Dzida (2019) reported in their study that the oil obtained from the lowest nitrogen dose application and the full bloom phase of the plants had the highest carvacrol content. The plant can uptake the nutrient (N) up to a certain optimum level and then reduce its use intensity. Accordingly, they reported that it can be explained by Voisin's maximum law, which is expressed as "the excess of a mineral in the soil limits the effectiveness of the others and reduces the yield".

Table 6. Data on nitrogen and phosphorus nutrients in sater with increasing nitrogen doses (mg kg^{-1})

Doses (kg da^{-1} N)	Nitrogen (N)			Phosphorus (P)		
	Cutting 1	Cutting 2	Mean	Cutting 1	Cutting 2	Mean
0	2.62 l	2.21 q	2.41 H	3734.50 c	3551.00 e	3642.75 B
5	2.58 m	2.47 n	2.52 G	2539.50 m	3623.50 d	3081.50 F
10	2.93 j	2.48 n	2.71 F	2670.50 l	3566.50 e	3118.50 E
15	3.96 c	2.28 p	3.12 C	2882.50 j	3845.50 b	3364.00 C
20	3.22 g	2.62 l	2.92 E	2705.50 k	3724.00 c	3214.75 D
25	3.53 f	2.78 k	3.15 C	2947.50 ı	4552.00 a	3749.75 A
30	4.02 b	2.99 ı	3.50 B	2485.00 n	3477.00 fg	2981.00 G
35	3.65 e	2.42 o	3.03 D	2361.00 p	3466.00 g	2913.50 I
40	3.78 d	2.49 n	3.14 C	2434.50 o	3310.50 h	2872.50 J
45	4.50 a	3.06 h	3.78 A	2419.50 o	3494.50 f	2957.00 H
Mean	3.48 A	2.58 B		2718.0 B	3661.05 A	
LSD (C)	0.01**			8.56**		
LSD (D)	0.05**			19.15**		
LSD (CxD)	0.03**			27.09**		

In terms of the effects of increasing nitrogen doses on nitrogen and phosphorus elements in sater plants, cutting, dose and cutting x dose interaction were found to be statistically significant at the 1% level. When Table 6 is examined; the nitrogen value obtained from the first cutting (3.48%) is higher than the value obtained from the second cutting (2.58%). When the nitrogen element values are examined in terms of applied nitrogen doses, the highest value was obtained from 45 kg da^{-1} N (3.78%) application, and the lowest value was obtained from control (2.41%) application. When the cutting x dose interaction values are examined, the highest nitrogen element value was obtained from 45 kg da^{-1} N (4.50%) application in the first cutting, and the lowest value was obtained from control (2.21%) application of the second cutting. When the nutrient element values obtained from previous studies are examined; Seidler-lozykowska et al. (2009) reported that the nitrogen value varied between 2.52-3.02% in their study, and between 0.36-1.46% in the study conducted by Bayram (2018). The nitrogen values obtained from this study were parallel to the nitrogen rate of Seidler-lozykowska et al. (2009) and higher than the nitrogen rate reported by Bayram (2018). When the mean cutting values were examined, it was seen that the phosphorus value obtained from the second cutting (3661.05 mg kg^{-1}) was higher than the phosphorus value obtained from the first cutting (2718.0 mg kg^{-1}). When the phosphorus content values were examined in terms of doses, the highest phosphorus value was obtained from 25 kg da^{-1} N (3749.75 mg kg^{-1}) application, while the lowest value was obtained from 40 kg da-1 (2872.50 mg kg^{-1}) N application. When the cut x dose interaction was examined, the highest phosphorus content was obtained from 25 kg da^{-1} N (4552.00 mg kg^{-1}) application of the second cutting, while the lowest value was obtained from 35 kg da^{-1} (2361.00 mg kg^{-1}) N application of the first cutting (Table 5). Gedik et al. (2022) reported that the phosphorus value varied between 2136.0-1253.0 mg kg^{-1} in their study on sater genotypes. It is seen that it is lower than the phosphorus value obtained from this study. Dizida et al. (2015) reported in their study that many factors such as fertilization dose and type, soil type, planting place, cultivated species and developmental stage affect macro and micro element contents.

Table 7. Data on potassium and calcium nutrients in sater with increasing nitrogen doses (mg kg^{-1})

Doses	**Potassium (K) (mg kg^{-1})**			**Calcium (Ca)**		
(kg da^{-1} N)	**Cutting 1**	**Cutting 2**	**Mean**	**Cutting 1**	**Cutting 2**	**Mean**
0	17635 f	17805 f	17720.00 D	13770 ı	18710 e	16240.00 D
5	1279 l	16850 g	14820.00 G	10225 m	18825 e	14525.00 H
10	14585 j	18830 e	16707.50 F	10395 lm	21040 a	15717.50 E
15	14585 j	19540 d	17062.50 E	10605 l	19535 cd	15070.00 F
20	14445 jk	18840 e	16642.50 F	11405 k	19675 bc	15540.00 E
25	15335 ı	22615 a	18975.00 A	11395 k	19755 bc	15575.00 E
30	15475 ı	19740 c	17607.50 D	11805 j	17675 f	14740.00 G
35	15495 ı	21450 b	18472.50 B	16480 g	19855 b	18167.50 B
40	14325 k	19670 cd	16997.50 E	15050 h	18710 e	16880.00 C
45	15925 h	19820 c	17872.50 C	19375 d	21235 a	20305.00 A
Mean	15059.50 B	19516.00 A		13050.50 B	19501.50A	
LSD (C)	53.82**			84.75**		
LSD (D)	120.35**			189.51**		
LSD (CxD)	170.20**			268.01**		

In terms of potassium and calcium elements in the Sater plant, the cutting, dose and cutting x dose interaction were found to be significant at the level of 1%. When the cutting periods were examined in terms of potassium values, which is a macronutrient element; the potassium value obtained from the second cutting was determined as 19516.00 mg kg^{-1}, while the potassium value obtained from the first cutting was determined as 15059.50 mg kg^{-1} (Table 7). When the average potassium values were examined in terms of doses, the highest potassium value was obtained from the 25 kg da^{-1} N (18975.00 mg kg^{-1}) application, and the lowest value was obtained from the 5 kg da^{-1} N (14820.00 mg kg^{-1}) application. When the cutting x dose interaction was examined, the highest potassium value was observed from the 25 kg da^{-1} N (22615 mg kg^{-1}) application of the second cutting, and the lowest value was observed from the 5 kg da^{-1} N (12790 mg kg^{-1}) application of the first cutting (Table 7). In the study conducted by Gedik et al. (2022), they reported that the potassium value was in the range of 13575.0-14680.0 mg kg^{-1}. The potassium value obtained from this study was found to be higher. When the values given in Table 8 are examined in terms of calcium nutrient element; it was seen that the calcium value obtained in the second cutting, 19501.50 mg kg^{-1}, was higher than the value obtained from the first cutting (13050.50 mg kg^{-1}). When the effect of applied nitrogen doses on calcium nutrient element was examined; the highest calcium value was obtained from 45 kg da^{-1} N (20305.00 mg kg^{-1}) application, and the lowest value was obtained from 5 kg da^{-1} N (14525.00 mg kg^{-1}) application. When the cutting x dose interaction was examined, the highest calcium value was statistically obtained from 10 kg da^{-1} (21040 mg kg^{-1}) and 45 kg da^{-1} N (21235 mg kg^{-1}) applications of the second form in the same group, and the lowest value was obtained from 5 kg da^{-1} N (10225.00 mg kg^{-1}) application of the first cutting (Table 7). In the study conducted by Gedik et al. (2022), they reported that calcium values ranged between 7510.0-36944.7 mg kg^{-1} and it was found to be higher than the calcium values obtained in this study.

Table 8. Data on iron and manganese nutrient elements in sater with increasing nitrogen doses (mg kg^{-1})

Doses	**Iron (Fe)**			**Manganese (Mn)**		
(kg da^{-1} N)	**Cutting 1**	**Cutting 2**	**Mean**	**Cutting 1**	**Cutting 2**	**Mean**
0	143.50 j	219.80 b	181.65 B	28.23 l	30.97 j	29.60 F
5	121.00 l	169.70 gh	145.35 H	22.16 n	28.99 l	25.57 H
10	107.45 o	140.45 k	123.95 I	26.02 m	31.92 ı	28.97 G
15	108.25 o	220.70 ab	164.47 E	28.75 l	43.14 c	35.94 D
20	112.85 n	176.90 f	144.87 H	30.14 k	36.94 g	33.54 E
25	122.65 l	194.10 d	158.37 F	30.09 k	46.09 b	38.09 C
30	144.00 j	202.65 c	173.32 C	34.00 h	38.90 e	36.45 D
35	151.90 ı	222.85 a	187.37 A	41.67 d	37.93 f	39.80 B
40	118.25 m	190.60 e	154.42 G	36.76 g	36.19 g	36.47 D
45	168.50 h	172.25 g	170.37 D	46.92 a	41.97 d	44.44 A
Mean	129.83 B	191.0 A		32.47 B	37.30 A	
LSD (C)	0.81**			0.25**		
LSD (D)	1.82**			0.56**		
LSD (CxD)	2.58**			0.79**		

When the variance analysis table of iron nutrient element in Sater plant is examined, dose and cutting x dose statistical interaction is significant at 1% level. When the cutting periods are examined in terms of iron values which are micronutrients; the iron value obtained from the second cutting (191.0 mg kg^{-1}) is higher than the iron value obtained from the first cutting (129.83 mg kg^{-1}). When the average iron content values are examined in terms of doses, it is seen that the highest iron content is obtained from 35 kg da^{-1} N (187.37 mg kg^{-1}) application and the lowest value is obtained from 10 kg da^{-1} N (123.95 mg kg^{-1}) application. When the cutting x dose interaction was examined, the highest iron content was determined from the 35 kg da^{-1} N (222.85 mg kg^{-1}) application of the second cutting, and the lowest value was determined from the 10 kg da^{-1} (107.45 mg kg^{-1}) and 15 kg da^{-1} N (108.25 mg kg^{-1}) applications of the first cutting, which were statistically in the same group (Table 8). In the study conducted by Gedik et al. (2022), iron nutrient element values were reported to vary between 252.45-462.95 mg kg^{-1}, and in the study conducted by Seidler-lozykowska et al. (2009), it was reported that the iron value varied between 330-634 mg kg^{-1}, and they obtained higher iron values than this study. When Table 8 is examined, in terms of the effect of increasing nitrogen doses on the micro nutrient element manganese in sater plants, cutting, dose and cutting x dose interaction were found to be statistically significant at 1%. When the averages belonging to the manganese nutrient element content were evaluated; while the manganese value obtained from the second cutting was 37.30 mg kg^{-1}, it was seen that the value in the first cutting was 32.47 mg kg^{-1}. When the manganese average values of nitrogen dose applications were examined, the highest manganese value was seen in the 45 kg da^{-1} N (44.44 mg kg^{-1}) application and the lowest value was seen in the 5 kg da^{-1} N (25.57 mg kg^{-1}) application. When the cutting x dose interaction was examined, the highest manganese value was obtained in the 45 kg da^{-1} N (46.92 mg kg^{-1}) application of the first cutting, while the lowest value was obtained in the 5 kg da^{-1} N (22.16 mg kg^{-1}) application of the first cutting. When the literature studies on nutrient elements were examined; Gedik et al. (2022) reported that it varied between 36.20-78.42 mg kg^{-1}, Seidler-lozykowska et al. (2009) between 28-164 mg kg^{-1}, and Bayram (2018) between 59-85 mg kg^{-1}. The manganese value obtained from this study was found to be lower than the values determined by Gedik et al. (2022), Seidler-lozykowska et al. (2009) and Bayram (2018).

Table 9. Data on copper and zinc nutrient elements in sater with increasing nitrogen doses (mg kg^{-1})

Doses	Copper (Cu)			Zinc (Zn)		
(kg da^{-1} N)	Cutting 1	Cutting 2	Mean	Cutting 1	Cutting 2	Mean
0	17.73 a	10.67 hıj	14.20 A	47.82 a	25.18 j	36.50 A
5	11.38 fgh	11.06 ghı	11.22 CD	31.71 c	28.18 gh	29.94 C
10	11.68 d-h	11.79 d-h	11.74 C	28.42 fgh	27.67 h	28.04 E
15	12.35 d-g	11.50 fgh	11.92 BC	28.14 gh	28.88 fg	28.51 E
20	9.63 ıj	11.52 fgh	10.58 D	29.75 de	28.81 fg	29.28 D
25	15.13 b	14.32 bc	14.72 A	30.16 d	35.00 b	32.58 B
30	12.72 def	10.86 ghı	11.79 C	28.20 gh	25.96 ıj	27.08 F
35	11.01 ghı	11.60 e-h	11.30 CD	27.73 h	28.33 fgh	28.03 E
40	9.15 j	13.16 cd	11.15 CD	26.05 ı	29.94 d	27.99 E
45	12.77 def	13.06 cde	12.91 B	30.97 c	29.02 ef	29.99 C
Mean	12.35	11.95		30.89 A	28.70 B	
LSD (C)	0.48			0.25**		
LSD (D)	1.07**			0.55**		
LSD (CxD)	1.52**			0.79**		

While no difference was observed between the cutting times for the micronutrient copper, dose and cutting x dose interaction were found to be significant at the 1% level. When the variance analysis table for the effect on zinc was examined, cutting, dose and cutting x dose interaction were found to be significant at the 1% level.

When the averages of copper nutrient element content of increasing nitrogen doses were examined; no difference was observed between the cutting times. When the average values of copper nutrient element were examined in terms of applied nitrogen doses, the highest values were statistically obtained from the control (14.20 mg kg^{-1}) and 25 kg da^{-1} N (14.72 mg kg^{-1}) applications in the same group, while the lowest value was obtained from the 20 kg da^{-1} N (10.58 mg kg^{-1}) nitrogen application. When the cutting x dose interaction values were examined, it was seen that the highest copper value was from the control (17.73 mg kg^{-1}) application of the first cutting, while the lowest value was from the 40 kg da^{-1} N (9.15 mg kg^{-1}) application of the first cutting (Table 9). In the study conducted by Gedik et al. (2022), copper values were reported to vary between 11.26-26.81 mg kg^{-1}, and Bayram (2018) copper values were reported to vary between 13-38 mg kg^{-1}, and these values are lower than the copper values obtained from the study. Seidler-lozykowska et al. (2009) reported that the copper value varied between 12.2-14 mg kg^{-1}, and they are similar to the copper values obtained from this study. When the average values of the zinc nutrient element content of the sater plant with increasing nitrogen doses are examined in Table 9; the average zinc value of the first cutting was determined as 30.89 mg kg^{-1}, while the average zinc value of the second cutting was determined as 28.70 mg kg^{-1}. When the zinc values were examined in terms of doses, the highest zinc value was obtained from the control (36.50 mg kg^{-1}) application, and the lowest zinc value was obtained from the 30 kg da^{-1} N (27.08 mg kg^{-1}) application. When the cutting x dose interaction was examined, the highest zinc content was obtained from the control (47.82 mg kg^{-1}) application of the first cut and the lowest value was obtained from the control (25.18 mg kg^{-1}) application of the second cutting (Table 9). When previous studies were examined; Gedik et al. (2022) reported that it varied between 16.63-57.96 mg kg^{-1}, Seidler-lozykowska et al. (2009) 35.7-130.1 mg kg^{-1}, and Bayram (2018) 14-45 mg kg^{-1}. When Table 10 is examined, in terms of the effect of increasing nitrogen doses on sodium element in sater plant, cutting, dose and cutting x dose interaction were found to be statistically significant at the level of 1%. When the values found in terms of sodium nutrient element were examined; the sodium value obtained from the second cutting (64.18 mg kg^{-1}) was higher than the value obtained from the first cutting (38.59 mg kg^{-1}). In terms of nitrogen doses, the highest value of sodium element was statistically obtained from the control (57.35 mg kg^{-1}) and 25 kg da^{-1} N (56.18 mg kg^{-1}) applications in the same group, while the lowest value was obtained from the 15 kg da^{-1} N (46.95 mg kg^{-1}) application.

Table 10. Data on sodium nutrient element in sater with increasing nitrogen doses (mg kg^{-1})

Doses	Sodium (Na)		
(kg da^{-1} N)	Cutting 1	Cutting 2	Mean
0	46.21 g	68.50 c	57.35 A
5	39.53 hı	53.88 f	46.70 F
10	33.41 k	75.55 a	54.48 B
15	35.47 j	58.43 e	46.95 F
20	38.78 ı	61.24 d	50.01 D
25	40.27 hı	72.09 b	56.18 A
30	39.89 hı	67.20 c	53.55 BC
35	36.41 j	68.70 c	52.55 C
40	34.59 jk	62.44 d	48.52 E
45	41.33 h	53.78 f	47.55 EF
Mean	38.59 B	64.18 A	
LSD (C)	0.59**		
LSD (D)	1.32**		
LSD (CxD)	1.88**		

When the cutting x dose interaction was examined, the highest sodium value was obtained from the application of 10 kg da^{-1} N (75.55 mg kg^{-1}) of the second form, and the lowest value was obtained from the application of 10 kg da^{-1} N (33.41 mg kg^{-1}) of the first cutting (Table 10). In the study conducted by Gedik et al. (2022), sodium values were reported to vary between 92.83-210.85 mg kg^{-1}, and it was observed that these values were higher than the sodium values obtained in this study.

Conclusion

In this study, it was investigated how the quality characteristics of *Satureja hortensis*, which is used as thyme and has an important place among medicinal and aromatic plants, changed with increasing nitrogen applications. Accordingly, plant nutrients were affected at different rates by the applied nitrogen doses. Sodium, potassium, copper and phosphorus had the highest values at 25 kg da^{-1} application, iron at 35 kg da^{-1} application, and manganese, calcium and nitrogen elements at 45 kg da^{-1} application. When the main essential oil components were examined, it was seen that nitrogen applications positively affected some components up to 25 kg da^{-1} dose, but essential oil components were not affected by applications above this dose. Crude protein ratio and essential oil yield increased parallel to increasing nitrogen doses. This increase in essential oil yield was due to the increase in herb yield caused by the applied nitrogen doses. This study is the first study on the agricultural characteristics of the sater plant in Kahramanmaras conditions and will both form the basis for future studies and shed light on the studies.

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Conflict of Interest

The authors declare that they have no conflict of interest.

Author's Contributions

N.G.K. Responsible for the setup and all stages of the trial, O.G. Responsible for the setup and all stages of the experiment and preparation of the article

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