The Effect of Nitrogen, Magnesium, and Iron Applications on the Nutrient Content of Parsley (*Petroselinum crispum*)

Utjecaj primjene dušika, magnezija i željeza na njihov sadržaj u peršinu (*Petroselinum crispum*)

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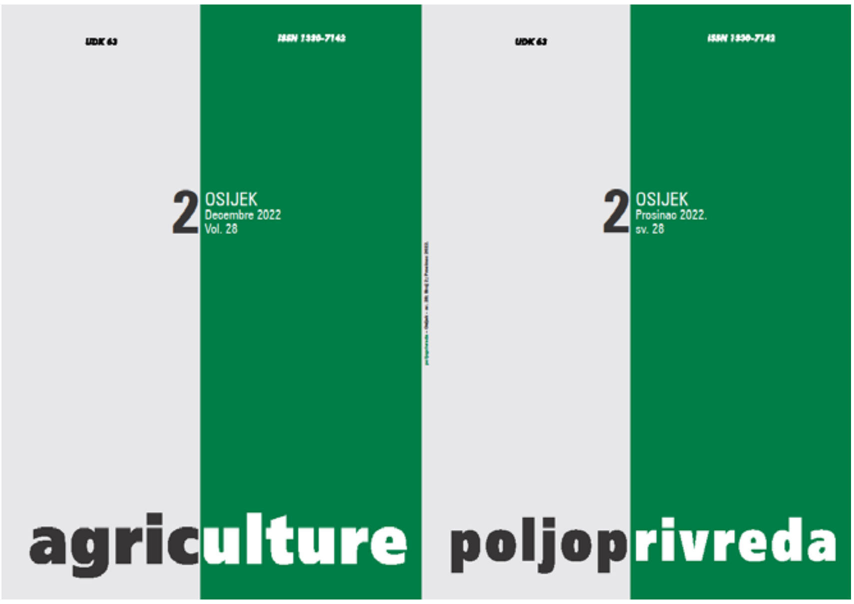

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THE EFFECT OF NITROGEN, MAGNESIUM, AND IRON APPLICATIONS ON THE NUTRIENT CONTENT OF PARSLEY (*Petroselinum crispum*)

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SUMMARY

The aim of this study is to investigate the effects of different rates of N, Mg, and Fe applications on the mineral content of parsley leaves. The experiment was carried out in a greenhouse according to the randomized plot design with three replications. Seven N, Mg, and Fe dose treatments were designed as 130, 160, 190, 220, 250, 280 and 310 kg per ha N as ammonium nitrate (33% N), 40, 80, 120, 160, 200, 240 and 280 kg per ha Mg as magnesium sulfate (16% MgO) and 8, 16, 24, 32, 40, 48 and 56 Fe kg per ha as ferrous sulfate (20% Fe). The treatments did not significantly affect the phosphorus concentrations in parsley leaves. The nitrogen uptake of the plant increased in all three element applications, and the highest N, K, and Ca values were determined in nitrogen fertilizer applications. The nitrate amount in the leaves also increased depending on the increasing N rates. The results indicate that the most effective fertilizer in the nutrition of parsley is nitrogen fertilizers and nitrogen doses up to 310 kg per ha did not increase the nitrate amount in parsley above the permissible level.

Keywords: ammonium nitrate, magnesium sulfate, ferrous sulfate, parsley, uptake nutrient

INTRODUCTION

In parsley cultivation, producers apply excessive nitrogen fertilization in order to remove the yellowing of the leaves and to obtain green or darker green plants. Especially, fertilizers in nitrate form are applied during the development period of the plants for increased yield and a better-quality production. This application causes nitrate and nitrite accumulation in green leafy vegetables, which are consumed more daily. Nitrite and nitrate from food are rapidly absorbed by the human body and, for the most part, excreted as nitrate. Some of the nitrate absorbed by the body is recirculated through salivary glands and part of it is converted by mouth bacteria into nitrite. Absorbed nitrite can oxidize hemoglobin to methemoglobin, an excess of which reduces the ability of red blood cells to bind and transport oxygen through the body. Nitrite in food (and nitrate converted to nitrite in the body) may also contribute to the formation of a group of compounds known as nitrosamines, some of which are carcinogenic (Hmelak Gorenjak and Cencic, 2013). The amount of nitrate adsorbed by the body varies according to the type of vegetables consumed, the nitrate level of the vegetable, the quantity of vegetables consumed, and the nitrate level in the water source (Pennington 1998). In many countries, the nitrate content of vegetables consumed is determined and the sale of products containing more than a certain amount of nitrate is not allowed (Siciliano et al., 1975; McKnight et al., 1999; Kavak et al., 2003). For this reason, a conscious fertilization program should be made instead of excessive nitrogen fertilization in parsley cultivation.

Yellowing of vegetable leaves can be caused not only by nitrogen deficiency but also by magnesium and iron deficiency (Elmacı and Yagmur, 2021). One-fifth of total Mg in plants is bound in chloroplasts, mainly as a

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key component of chlorophyll molecules (Verbruggen and Hermans, 2013). In addition, many photosynthetic enzymes involved in carbon fixation in chloroplasts are activated by Mg^{2+} (Lundqvist and Schneider, 1991). Plant growth is greatly inhibited under Mg deficiency stress, which leads to detrimental effects on crop productivity and quality in agricultural systems (Aitken et al., 1999). Significant yield improvement in response to magnesium (Mg) fertilization has been reported for a range of crops all over the world (Çakmak et al, 1999; Pourranjbari Saghaiesh, 2019; Guo et al., 2016). In a recent meta-analysis by Wang et al., (2020), Mg fertilizer application on average increased vegetable yields by 8.9% and such increase was most evident when soil Mg is severely deficient (ex-Mg $< 60\,mg\,kg^{-1}$). Iron is essential for the synthesis of chlorophyll and reduction of nitrate and sulfate, as well as assimilation of molecular nitrogen (N_2) (Madhava Rao et al., 2006). Iron deficiency reduces pigment content in the plant (chlorophyll, carotene, xanthine, and lutein) and chlorosis appears on young leaves (Madhava Rao et al., 2006), especially on alkaline soils (Herak Ćustić et al. 2008; López-Millán et al., 2009). To alleviate Fe deficiency of plants, Fe application in conventional mixed fertilizers is still the most prevalent to improve crop yields especially in greenhouse production systems; however, Fe applied with conventional fertilizers are often ineffective with a low nutrient-use efficiency (Laurie et al., 1991; Connorton et al., 2017).

Our hypothesis is that a conscious fertilization will support an economically viable and environmentally compatible parsley production, compared to conventional fertilizations. The objective of the research was to determine the effects of different rates of N, Mg, and Fe fertilizations on the mineral content of parsley leaves.

MATERIAL AND METHODS

A greenhouse experiment was conducted during one growing season of parsley from March to May in 2020 at Menemen, Turkey. The physicochemical characteristics of the experiment soil were given in Table 1.

Table 1. General soil properties of the experiment field
Tablica 1. Karakteristika tla pokusne površine

Soil taxonomy / *Karakteristike tla*	Xerofluvent	Available, mg kg^{-1} / *Pristupačni elementi mg kg^{-1}*	K	214
Texture / *Tekstura*	Clay loam		Ca	3472
pH (1:2.5 w/v H_2O)	7.50		Mg	138
Organic matter, % / *Organska tvar, %*	1.04		Fe	3.16
Total soluble salt, % / *Topive soli, %*	0.024		Mn	17.91
Total N, % / *Ukupni N, %*	0.060		Cu	0.94
Available P, mg kg^{-1} / *Pristupačni P, mg kg^{-1}*	4.22		Zn	1.27

The used parsley cultivar was Giant of Italy. The experiment was carried out in 2.5 L plastic pots according to the randomized plot design with three replications, in 66 pots. Twenty-five seeds were planted in each pot. Seven N, Mg, and Fe dose treatments were designed as 130, 160, 190, 220, 250, 280 and 310 kg per ha N as ammonium nitrate (33% N), 40, 80, 120, 160, 200, 240 and 280 kg per ha Mg as magnesium sulfate (16% MgO) and 8, 16, 24, 32, 40, 48 and 56 Fe kg per ha as ferrous sulfate (20% Fe). As a control application, NPK 15-15-15 compound fertilizer was applied at a rate of 100 kg per ha. Initially, the pots were irrigated daily at 60% of their water holding capacity. During the development period, this amount reached 80% of the water holding capacity. Harvesting was done by hand after two months. Plant samples were overdried (75 °C) and grounded for concentration determinations of mineral nutrients (N, P, K, Ca, Mg and Fe). The total nitrogen was determined according to the Kjeldahl method (Kacar and Inal, 2008). The total phosphorus was measured by a colorimetric determination using the Vanadomolybdo phosphoric yellow color method on the wet- digested (4 parts HNO_3 + 1-part $HClO_4$) dry sample (Lott et al. 1956). Total potassium and calcium were determined on the wet-digested samples with a flame photometer and total magnesium and iron with atomic absorption spectrophotometer in same samples (Kacar and İnal 2008; Kacar, 1972). The nitrate content of parsley was determined colorimetrically in the complex formed by nitration of salicylic acid (Cataldo et al., 1976). The data were expressed as a percentage or mg/kg of dry matter (DM) and analyzed by a one-way ANOVA followed by Tukey-Kramer test. Significant differences were reported at the $p < 0.05$ level of confidence. JMP 5.0.1 software was used for statistical analyses.

RESULTS AND DISCUSSION

The effect of nitrogen fertilizer applications on mineral content of parsley

Nitrogen has a pronounced influence on plant growth and development, and all economically important horticultural crops have recommended N rates for optimal yield (Chenard et al., 2007). The effect of nitrogen fertilizer applications on the total nitrogen, phosphorus, potassium, calcium, magnesium and iron content of the parsley plant is given in Table 2. Macronutrient and Fe accumulation in the leaves of parsley responded significantly to N treatment concentrations. Significant responses to N treatments were observed for N ($P \leq 0.01$), K ($P \leq 0.05$), Ca ($P \leq 0.05$), Mg ($P \leq 0.05$), Fe ($P \leq 0.01$) and NO_3-N ($P \leq 0.01$) in parsley leaf tissues. Although significant response to N treatments was not determined for P, the concentrations of P increased due to increasing N doses. While the highest total N content was determined at 220 and 250 kg per ha N doses and the highest total K, Ca, Mg and Fe contents were determined at 220 kg per ha N dose. At higher N rates, the concentrations of the element significantly decreased. Accumulation of macronutrients in response to increasing N rates may have dietary nutritional importance (Chenard et al., 2007). Parsley ranks behind only turnip greens (*Brassica rapa* L.), garlic (*Allium sativum* L.), and kale (*Brassica oleracea* var. *acephala* DC) for Ca content, and behind beet greens (*Beta vulgaris* L.), potatoes (*Solanum tuberosum* L.), and spinach (*Spinacia oleracea* L.) for K content (Maynard and Hochmuth, 1997). The highest levels of tissue N, K, Ca, Mg and Fe were generally found with 220 kg per ha N, indicating that increases in N nutrition greatly enhance nutrient content of parsley leaves. In parallel with the increase in nitrogen doses, the nitrate amount in the leaves also increased and the highest nitrate amount was determined at the highest nitrogen dose (310 kg per ha). Parsley is one of the leafy vegetables that can accumulate nitrate in the range of 1000-2500 mg kg^{-1} (Blom-Zandstra, 1989). European Commission has nitrate limit for some vegetables but there is no limit for parsley. Acceptable daily intake (ADI) amount for nitrate was determined by the Scientific Committee on Food (SCF) as 0 to 3.7 mg kg^{-1} body weight/day, which is equivalent to the intake of 222 mg nitrate/day for an adult weighing 60 kg and 0.07 mg kg^{-1} body weight/day for nitrite (FAO/WHO, 2013). According to FAO/WHO nitrate limits (2013), even the highest nitrate amount detected in the study is within the permissible levels for humans. The lowest total N, P, K, Ca, Mg, Fe and NO_3-N concentrations were measured at control plants.

Table 2. The concentrations of mineral nutrients (N, P, K, Ca, Mg and Fe) in parsley plant as affected by N application rate

Tablica 2. Utjecaj primjene N na koncentraciju nutrijenata (N, P, K, Ca, Mg i Fe) u peršinu

Treatments kg ha^{-1} N / *Tretmani kg ha^{-1} N*	Total[1)] / *Ukupni[1)]*						
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (mg kg^{-1})	NO_3-N (mg kg^{-1})
Control / *Kontrola*	2.97d	0.31	2.91e	1.26d	0.36c	42.30e	685.30c
130	4.23c	0.39	3.22c	1.72c	0.42b	55.70d	814.70bc
160	4.26c	0.40	3.45bc	1.93ab	0.47b	68.40c	827.60b
190	4.42b	0.42	3.54b	1.96a	0.52a	75.60b	830.70b
220	4.73a	0.43	3.61a	1.96a	0.57a	89.20a	842.20b
250	4.82a	0.45	3.52b	1.93ab	0.48b	68.70c	857.90b
280	4.45b	0.45	3.38c	1.81b	0.38c	68.20c	900.60ab
310	4.45b	0.40	3.14d	1.78c	0.39c	67.90c	913.70a
P	**	ns	*	*	*	**	**

[1)]All values are given based on dry matter (DM) / *Sve vrijednosti iskazane na suhoj tvari (DM)*

*: P≤0.05, **: P≤0.01, ns: not significant / *nije značajno*

The effect of magnesium fertilizer applications on mineral content of parsley

Magnesium is a necessary nutrient for performance of the plant main physiological functions. It participates in photosynthesis process as a constituent of a chlorophyll molecule; it is an important agent in the process of phosphorus transport within the plant; it takes part in the synthesis of sugars and transport of starch, as well as in several other physiological and biochemical processes (Roemheld and Kirkby, 2007). The magnesium fertilization plays an important role in increase of productivity, crop protection and green color that is one of the required quality specifications (Piagentini et al., 2002 and Hao and Papadopoulos, 2004). The effect of magnesium fertilizer applications on the total nitrogen, phosphorus, potassium, calcium, magnesium, and iron content of the parsley plant is given in Table 3.

Table 3. The concentrations of mineral nutrients (N, P, K, Ca, Mg, and Fe) in parsley plant as affected by the Mg application rate

Tablica 3. Utjecaj primjene Mg na koncentraciju nutrijenata (N, P, K, Ca, Mg i Fe) u peršinu

Treatments kg ha^{-1} Mg / *Tretmani kg ha^{-1} Mg*	Total[1] / *Ukupni[1)]*					
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (mg kg^{-1})
Control / *Kontrola*	2.97d	0.31	2.91	1.26	0.36e	42.30d
40	3.47c	0.39	3.04	1.42	0.42d	54.60c
80	3.47c	0.43	3.22	1.65	0.51c	55.80c
120	3.56bc	0.45	3.45	1.71	0.56c	57.30bc
160	3.61b	0.49	3.54	1.98	0.72b	63.40b
200	3.75b	0.36	3.19	1.40	0.85a	68.20a
240	3.78ab	0.35	3.12	1.39	0.78b	64.70b
280	3.84a	0.35	3.10	1.35	0.72b	53.90c
P	*	ns	ns	ns	**	**

[1)]All values are given based on dry matter (DM) / *Sve vrijednosti iskazane na suhoj tvari (DM)*

*: P≤0.05, **: P≤0.01, ns: not significant / *nije značajno*

Significant responses to the Mg treatments were observed for N ($P \leq 0.05$), Mg ($P \leq 0.01$), and Fe ($P \leq 0.01$) in parsley leaf tissues. In contrast, P, K, and Ca concentrations in parsley leaves were not affected by the Mg fertilizer application. While the highest total N content was determined at 240 and 280 kg per ha, the Mg doses and the highest total Mg and Fe contents were determined at 200 kg per ha Mg dose. At higher Mg rates, the concentrations of Mg and Fe significantly decreased. El-Aleem and colleagues (2016) determined gradual increments in N, P, K and Mg contents with increasing magnesium levels. These results agree with those of El-Wahab and Mohamed (2007), Fajemilehin and colleagues (2008) and Khalid and colleagues (2009), who reported that the content of N and Mg of plant showed enhanced response to magnesium application.

The effect of iron fertilizer applications on mineral content of parsley

Since iron is stored at very low levels in plants and its transport from old to young organs is difficult, iron must be constantly present in soil for the normal plant development. Iron is an essential element for chlorophyll biosynthesis. Since iron is an immobile element, it cannot be transported from old leaves to young leaves, and deficiency symptoms are primarily observed in the young leaves. The typical symptom of iron deficiency is yellowing between the leaf veins (Yağmur and Elmacı, 2021). The effect of iron fertilizer applications on the total nitrogen, phosphorus, potassium, calcium, magnesium, and iron content of the parsley plant is given in Table 4.

Significant responses to Fe treatments were observed for N ($P \leq 0.05$), K ($P \leq 0.05$), Mg ($P \leq 0.01$), and Fe ($P \leq 0.01$) in parsley leaf tissues. In contrast, P and Ca concentrations in parsley leaves were not affected by Fe fertilizer application. While the highest total N content was determined at 56 kg per ha Fe dose and the highest total K and Fe contents were determined at 48 and 56 kg per ha Fe doses. Mg concentration in parsley leaves reached the highest level at 32 kg per ha Fe dose. Increasing doses of iron applications increased the mineral content of the parsley plant. The results obtained as a result of the study carried out with increasing doses of nitrogen, magnesium and iron fertilizer applications are similar to the findings of many researchers (Atta-Aly 1999; Sancaktaroğlu, 1999; Eşiyok et al., 1999; Fırattekin et al., 2000; Eşiyok et al., 2001; Ceylan et al., 2005; Özhan et al., 2018; Yağmur et al., 2018).

Table 4. The concentrations of mineral nutrients (N, P, K, Ca, Mg and Fe) in parsley plant as affected by Fe application rate

Tablica 4. Utjecaj primjene Fe na koncentraciju nutrijenata (N, P, K, Ca, Mg i Fe) u peršinu

Treatments kg ha^{-1} Fe / *Tretmani kg ha^{-1} Fe*	Total[1] / Ukupni[1)]					
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (mg kg^{-1})
Control / *Kontrola*	2.97d	0.31	2.91d	1.26	0.36c	42.30f
8	3.22c	0.33	2.94cd	1.26	0.39b	60.40e
16	3.42c	0.37	3.05c	1.32	0.39b	66.90d
24	3.45c	0.42	3.12c	1.36	0.41b	81.20c
32	3.59b	0.42	3.24b	1.41	0.47a	93.70b
40	3.61b	0.43	3.36ab	1.39	0.44ab	95.30b
48	3.65b	0.41	3.41a	1.36	0.42b	98.70a
56	3.73a	0.40	3.42a	1.25	0.37c	98.50a
P	*	ns	*	ns	**	**

[1)]All values are given based on dry matter (DM) / *Sve vrijednosti iskazane na suhoj tvari (DM)*

*: P≤0.05, **: P≤0.01, ns: not significant / *nije značajno*

CONCLUSION

As a result, it was determined that N, Mg, and Fe applications to soil did not affect the phosphorus concentration in parsley leaves at all but have increased the uptake of other elements. The nitrogen uptake of the plant increased in all three element applications and the highest N, K, and Ca values were determined in nitrogen fertilizer applications. The nitrate amount in the leaves also increased depending on the increasing N rates and the highest nitrate amount was determined at the highest nitrogen dose (310 kg per ha). However, even the highest nitrate amount is within the permissible levels for humans determined by FAO/WHO. These results indicate that the most effective fertilizer in the nutrition of parsley is nitrogen fertilizers and nitrogen doses up to 310 kg per ha did not increase the nitrate amount in parsley above the permissible level.

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UTJECAJ PRIMJENE DUŠIKA, MAGNEZIJA I ŽELJEZA NA NJIHOV SADRŽAJ U PERŠINU (*Petroselinum crispum*)

SAŽETAK

Cilj ovoga istraživanja bio je analizirati učinak primjene N, Mg i Fe na sadržaj minerala u lišću peršina. Pokus je proveden u stakleniku prema nasumičnome rasporedu u tri ponavljanja. Sedam tretmana N, Mg i Fe dodano je na sljedeći način: 130, 160, 190, 220, 250, 280 i 310 kg ha^{-1} N kao amonijev nitrat (33% N), 40, 80, 120, 160, 200, 240 i 280 kg ha^{-1} Mg kao magnezijev sulfat (16% MgO) i 8, 16, 24, 32, 40, 48 i 56 kg ha^{-1} Fe kao željezov sulfat (20% Fe). Tretmani nisu značajno utjecali na koncentraciju fosfora u lišću peršina. Apsorpcija dušika u biljci povećala se pri primjeni svih triju elementa, a najviše vrijednosti N, K i Ca utvrđene su pri primjeni dušičnih gnojiva. Količina NO_3^--N u lišću također se povećala ovisno o porastu koncentracije dodanoga dušika. Rezultati pokazuju da su u ishrani peršina dušična gnojiva najučinkovitije, a količina dušika do 310 kg ha^{-1} nije dovela do povećanja količine NO_3^- N u lišću peršina iznad dopuštene razine.

Ključne riječi: amonijev nitrat, magnezijev sulfat, željezov sulfat, peršin, unos hraniva

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