

Use of nitrogen fertilizers under the influence of sulphur at two varieties of spinach (*Spinacia oleracea* L.)

Gocan Tincuța-Marta¹, Andreica Ileana¹, Rosza S.¹, Moldovan Ioana¹, Lazar V¹, Poșta G.^{2*}

¹University of Agricultural Sciences and Veterinary Medicine, Faculty of Horticulture, 400372, 3-5 Mănăștur Street, Cluj-Napoca, România; ²Banat University of Agricultural Sciences and Veterinary Medicine „King Michael I of Romania”, Faculty of Horticulture and Forestry, Timișoara, România

*Corresponding author e-mail: posta.gheorghe@gmail.com

Abstract Sulphur has a wide use in the industry. The experiment was performed in the year of 2017, at the Didactic Resort of the USAMV Cluj-Napoca. A vegetation pot experiment was established to explore the effect of two doses of nitrogen (0.6 and 0.9 g N in the form of ammonium sulphate) and two doses of sulphur (20 and 30 mg/kg of soil) on the yields and quality of spinach in comparison with a natural level (7.60 mg/kg). Spinach biomass increased when adding the first sulphur rate. Higher nitrogen dosages slightly increased yields and sulphur at S1 and S2 increased significantly compared to sulphur-free fertilizer. Increasing the doses of N2 nitrogen widened the N:S ratio. Regardless of the variety in the experience, the nitrate content in the spinach corresponds to the applied nitrogen dose and the nitrogen concentration. There were no statistically significant differences in nitrogen and sulphur doses. The sulphur level did not affect the vitamin C content.

Key words

spinach, sulphur, fertilizer, nitrate, C vitamin, yield

Sulphur is one of the essential elements for animals and plants. In addition to playing a vital role in living organisms, it has a very important use in industry as an ingredient in some chemicals, fertilizers, fungicides, pesticides, pharmaceuticals [11]. The fact that crop deficiencies of sulphur (S) have been reported with increasing frequency over the past several years greater attention has been focused on the importance of this element in plant nutrition [14].

Exploiting soils even in protected spaces can affect its contents. Soil fertility may decline after plant cultivation, due to direct uptake into harvest materials or through indirect leaching [5]. Optimum nutrition is essential for obtaining high-quantity and high-quality produce [16]. Compared to other agricultural crops, vegetables have very high requirements for nutrients available in the soil [17].

Sulphur and its content in plants are also closely related to the nutritional value of vegetables. Estimating the dose and the optimal sulphur-form in terms of its soil content before sowing and/or planting the vegetables is of decisive importance for the supply of this plant element [6]. The importance of sulphur in agriculture is obvious because plants require sulphur for synthesis of an essential amino acid and proteins, certain vitamins and coenzymes, glucoside oils, structurally and physiologically important disulphide linkages and sulphhydryl groups, and activation of certain enzymes [4]. Sulphur addition showed no effect at the lowest nitrogen fertilizer rate, but nitrogen uptake was increased when sulphur was applied at the

highest nitrogen rate, revealing a synergism between both nutrients [12].

The mobility of sulphur in the plants is lower. The transport of sulphur is acropetally, from the roots into the young leaves and meristems; sulphur cannot be transported from the older leaves into the young ones. The SO_4^{2-} content may be an indicator of the plants supply of sulphur [18]. Concerning the conditions of sulphur deficiency and/or sulphur, they cause decrement in the osmotic potential [7], in the chlorophyll content, provoking chlorosis of young leaves [10].

Spinach is traditionally consumed cooked, although it can be consumed raw, in salads or shakes. It can be found fresh, with no further process, minimally processed and also processed by canning and freezing. Spinach has a high nutritional value and is extremely rich in antioxidants, especially when fresh, steamed, or quickly boiled it is a rich source of vitamin C, vitamin E, vitamin K [15]. It is also a good source of folic acid and iron [2]. It has a high nutritional value due to its unusually high iron content (Fe).

Nitrate accumulation in leafy vegetables such as rocket, spinach has a detrimental impact on human health [1].

Material and Methods

Experience has been established at the Didactic Resort of the USAMV Cluj-Napoca; two varieties, Dolphin and Matador, were sampled. Chemical analyses took place in the Horticultural Technology Laboratory of

ICHAT Cluj-Napoca. Chemical analysis and physical properties of the experimental soil are shown in Table

no. 1.

Table 1

Agrochemical properties of soil before the establishment of the experiment

Available nutrients (mg/kg soil)				S water (mg/kg)
P	K	Mg	Ca	
225	265	90	1520	7.60

Fertilisation was performed on April 15, 2017. All the fertilisers were applied prior to spinach sowing. The natural content of sulphur in the soil was 7.60 mg/kg in variants. Nitrogen was supplemented in the form of NH_4NO_3 . The two varieties of spinach were supplemented with a dose of nitrogen on the level of $\text{N1} = 0.6 \text{ g}$ and $\text{N2} = 0.9 \text{ g}$. The application of $(\text{NH}_4)_2\text{SO}_4$ modified the level of water-soluble S to 20 mg/kg and 30 mg/kg the data are given in table 2.

Harvesting leaves for analysis and chemical determinations were performed after May 26. Determination of dry matter was done both at the oven [3] and hand refractometer [8]. C vitamin was determined by the iodometric method, the nitrates level with photocolormetry [3]. The statistical processing was performed with ANOVA program for both statistical interpretations.

Table 2

Experimental scheme

Variant	Experimental scheme	S water (mg/kg)	Nutrient level (g/plot)	
			N NH_4NO_3	S $(\text{NH}_4)_2\text{SO}_4$
Dolphin	N1S0	6.0	0.6	-
	N2S0		0.9	
Matador	N1S0		0.6	
	N2S0		0.9	
Dolphin	N1S1	20	0.6	0.60
	N2S1		0.9	
Matador	N1S1		0.6	
	N2S1		0.9	
Dolphin	N1S2	30	0.6	1.05
	N2S2		0.9	
Matador	N1S2		0.6	
	N2S2		0.9	

Results and Discussions

Tables no. 3 and no. 4, shows that higher doses of nitrogen have slightly increased yields and that sulphur at S1 and S2 levels has increased statistically significantly compared with sulphur-fertilized variants. There were no statistically significant differences in nitrogen and sulphur doses even if the sulphur was supplemented with 10 mg / kg. It can be said from the results obtained that the addition of sulphur increased

the biomass of spinach in both varieties, fact recorded also by other authors [13].

The leaf weight, depending on the experimental factors in the Dolphin variety, ranged between 73.4 g (N2S0) and 125.4 g (N1S2). The relative increase compared to the N1S0 variation was 54.1%. Depending on S1 = 20.6 mg / kg, the second highest yield was reported (Table 3). Maryam and Naser [9] results indicated that different levels of nitrogen fertilizer on all growth characteristics were significant.

Table 3

Average yields of Dolphin and contents of N and S in dry matter/ plant fresh

Variant	Experimental scheme	Average weight of spinach leaves / plant fresh			Content in dry matter (%)	
		(g)*	rel. %	dry matter (g)	N	S
V1	N1S0	83.30d	100.0	8.8	4.60	0.193
	N2S0	73.60e	88.4	8.6	4.62	0.200
V2	N1S1	125.55a	160.7	11.4	5.20	0.486
	N2S1	120.50b	144.7	11.2	5.22	0.483
V3	N1S2	124.10ab	149.0	11.3	5.39	0.560
	N2S2	112.55c	135.0	11.0	5.28	0.573

LSD 0.05 = 4.05, LSD 0.01 = 6.35

**DS = 4.04-4.25 (Duncan test)*

With the increase in the nitrogen dose, the ratio of N:S increased regardless of the variety. The ratio of N:S for Dolphin in the dry substance shown in

Figure no. 1 was lower for plants where the sulphur dose was higher. Values ranged from 9.22 (N2S2) and 23.84 (N1S0).

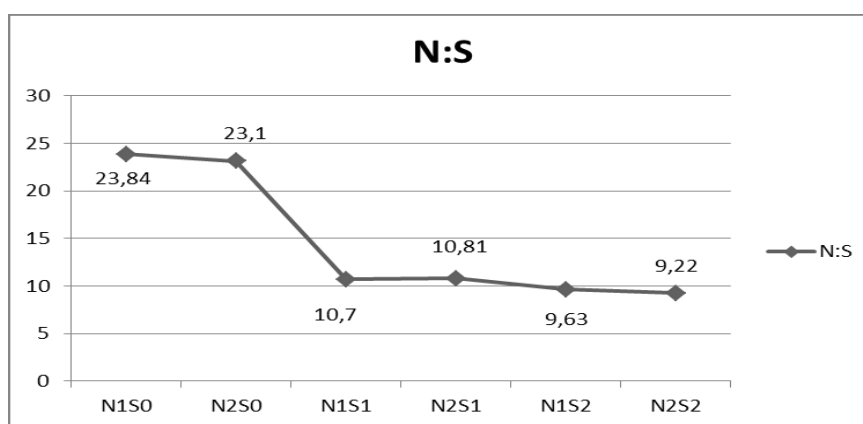


Fig. 1. The influence of nitrogen and sulphur ratio to the Dolphin dry matter content

The Matador variety presented in Table no. 4, recorded slightly lower values than Dolphin, keeping the same variants at the lowest amount of leaves on the 71.4 g (N2S0) on plant. In this variety, the total dry matter

content of the leaves recorded the best values for the 20 mg / kg (N1S1 and N2S1) sulphur rate, respectively 10.6 g and 10.5 g. The nitrogen content recorded values of 5.00 (N2S0) and 5.58 (N1S2).

Table 4

Yields average of Matador and contents of N and S in dry matter / fresh plant

Variant	Experimental scheme	Average weight of spinach leaves / fresh plant			Content in dry matter (%)	
		(g)*	rel. %	dry matter (g)	N	S
V4	N1S0	82.3d	100.0	7.9	5.10	0.210
	N2S0	71.4e	86.7	7.6	5.00	0.198
V5	N1S1	123.6a	150.1	10.8	5.52	0.465
	N2S1	119.2b	144.8	10.6	5.49	0.495
V6	N1S2	122.3a	148.6	10.5	5.58	0.558
	N2S2	105.2c	128.6	10.3	5.56	0.545

LSD 0.05 = 2.20, LSD 0.01 = 3.46

**DS = 2.21-2.31 (Duncan test)*

The nitrogen / sulfur ratio for the Matador variety to the dry substance is shown in Figure 2. It was smaller, regardless of the variety for plants where the sulfur

dose was higher, but compared to the Dolphin variety, which grew slightly. Values ranged from 10.1 g (N2S2) and 25.26 g (N1S0).

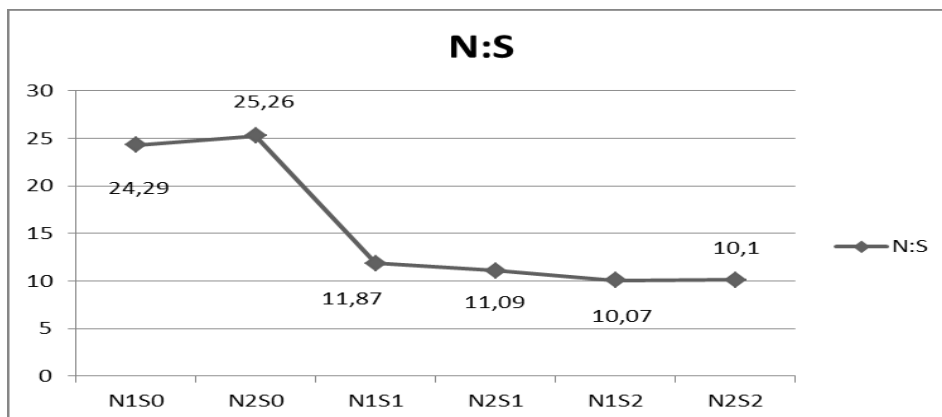


Fig. 2. The influence of nitrogen and sulphur ratio to the Matador dry matter content

Nitrate accumulation in leafy vegetables such as rocket, spinach has a detrimental impact on human health [14].

The situation for the Dolphin variety with respect to the chemical composition of the fresh leaf material in Table no. 5 is presented: the amount of soluble dry

substance having close values for all variants, but the largest quantity obtained the variants with 20% sulphur (N1S, N2S1). Nitrate accumulation in spinach leaves recorded acceptable values for all variants, the highest were in sulphur-free variants.

Sulphur has not affected the amount of ascorbic acid.

Table 5

Content of TSS, nitrates, ascorbic acid, N and S consumption at Dolphin variety

Variant	Experimental scheme	TSS (°brix)	Fresh matter		Total consumption of elements (g/plot)	
			NO ₃ ⁻ (mg/kg)	ascorbic acid (ppm)	N	S
V1	N1S0	8.4	4630	56.8	0.386	0.017
	N2S0	8.9	4620	51.9	0.372	0.016
V2	N1S1	9.8	2535	44.8	0.587	0.052
	N2S1	9.6	3545	46.2	0.612	0.055
V3	N1S2	8.8	3206	49.7	0.643	0.060
	N2S2	8.6	2317	51.9	0.627	0.058

Figure 3 shows the ratio N: S in the case of the Dolphin variety in relation to the total consumption of the

elements, noting that when the two sulfur doses are 20% and 30% the ratio decreases.

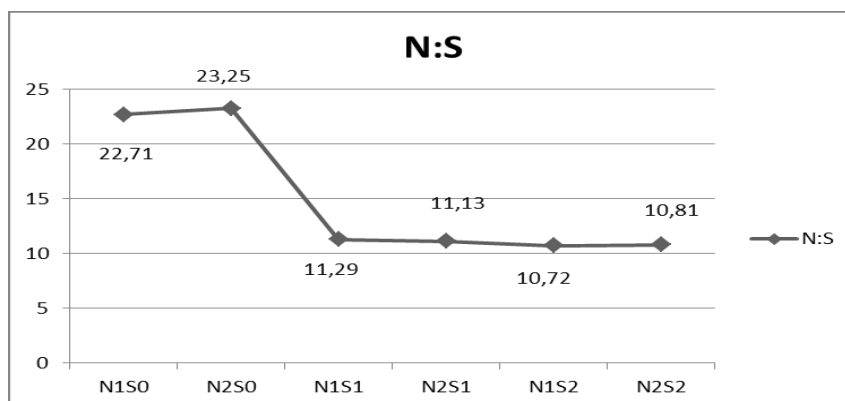


Fig. 3. The influence of N:S ratio on total consumption of elements (g/plot) at Dolphin variety.

Table 6 shows the amount of soluble dry substance for Matador variety, which is almost similar to the Dolphin variety, being slightly lower in all variants, the latter

being the N2S2 variant with 8.2%. The administration of sulphur doses did not influence the content of nitrates and C vitamin.

Table 6

Content of TSS, nitrates, ascorbic acid, N and S consumption at Matador variety						
Variant	Experimental scheme	TSS (°brix)	Fresh matter		Total consumption of elements (g/plot)	
			NO ₃ ⁻ (mg/kg)	ascorbic acid (ppm)	N	S
V1	N1S0	8,4	4632	55.7	0.315	0.016
	N2S0	8,5	3235	50.2	0.313	0.014
V2	N1S1	9,2	2542	41.8	0.632	0.056
	N2S1	9,0	3144	40.2	0.614	0.053
V3	N1S2	8.6	3226	46.3	0.633	0.058
	N2S2	8.2	2518	38.4	0.609	0.057

Following the N: S ratio in the case of the Matador variety, in relation to the total consumption of

elements, a slight decrease was observed, wich is not influenced by the sulfur addition (Figure no. 4).

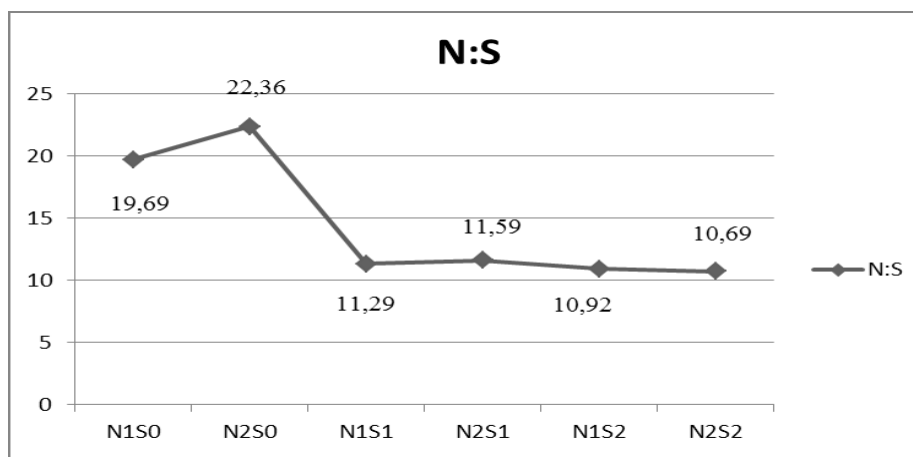


Fig.. 4. The influence of N:S ratio on total consumption of elements (g/plot) at Matador variety.

Conclusions

Efficiency of nitrogen use increased when sulphur fertilizer was added, it can be said to be variable because it includes both soil and plant chemical processes.

Increasing the yield of spinach leaves in response to sulphur addition was associated with a higher rate of nitrogen uptake before synthesis, confirming the positive interaction between both nutrients.

Sulphur addition, showed no effect at the lowest nitrogen fertilizer rate, but nitrogen uptake was increased when sulphur was applied at the highest nitrogen rate, revealing a synergism between both nutrients.

The administration of sulphur doses did not influence the amount of ascorbic acid in either of the two varieties taken in the experience.

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