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[1] Department of Agrochemistry, Soil Science, Microbiology and Plant Nutrition
Mendel University of Agriculture and Forestry, Brno, Zemědělská 1, 613 00 Brno
Czech Republic, losak@mendelu.cz
[2] Department of Agricultural Chemistry, Agricultural University of Cracow
al. A. Mickiewicza 21, 31-120 Kraków, Poland

Tomáš Lošák[1], Barbara Wiśniowska-Kielian[2]

Fertilization of garlic (Allium sativum L.) with nitrogen and sulphur

ABSTRACT. In a vegetation pot trial the effect of three graded levels of sulphur in the soil (S_0 = 18.3; S_1 = 40; S_2 = 60 mg S-SO_4 kg^{-1}) was explored under constant nitrogen nutrition (0.6 g N pot^{-1}) on the yields and quality of spring garlic. Sulphur was applied as ammonium sulphate and nitrogen was maintained at a uniform level with ammonium nitrate. Mitscherlich's pots were filled with medium heavy fluvial soil, which showed weak acid reaction, good supply of available phosphorus and potassium, high calcium content and very high magnesium content. Narrow-leaved spring giant garlic, variety 'Prim', were planted and harvested in the stage of full maturity. The amount of the yield was evaluated and nitrate content was measured direct in green plants with ion-selective electrode. Under the influence of the higher dosage of sulphur introduced to the soil the yields increased statistically significantly by as much as 9.8% compared with the control variant and by 6% compared to the lower dose of sulphur. With increasing sulphur levels in the soil the reduction of nitrates concentrations in edible parts of garlic was highly significant, i.e. by 9.5 to 22.7% compared to the control treatment. The permitted limit of nitrates according to the Regulations of the Ministry of Health No. 53/2002 Sb was not exceeded in any variant.

KEY WORDS: garlic, nitrogen, sulphur, yields, nitrates

Garlic (*Allium sativum*, L.) is one of the oldest cultivated vegetables and its positive effect on human organism has been known for thousands years. In botanical terms the edible part of garlic is composed of garlic cloves. Garlic contains about 30–35% dry matter, 6–7% proteins, 0.2% lipids, 23–28% carbohydrates, 0.7–0.9% fibre, 1.1–1.4% ash matter and vitamins, especially B_1, B_2, B_6 and C. Garlic also contains antibiotics garlicin and allistatin, a number of enzymes, amino acids, universal substances, including trace elements. Garlic is consumed directly, or to add flavour to food, in smoked-meat products and for the production of medicaments. At present it is valued for its content of essential oils [Malý et al. 1998].

To achieve the required yields and quality, nutrition of garlic with macro- and microbiogenic elements must be well balanced. Compared to other agricultural crops the demands of garlic for nutrients are relatively high; sulphur is very important for bulbous vegetables in terms of yields and quality. A restricted use of mineral and organic fertilisers, fungicides and a considerable reduction of SO_2 emissions contributed to the present deficiency of this macrobiogenic element in many countries, which is reflected particularly in plants with high demands for sulphur, among them bulbous vegetables [Motowicka-Terelak, Terelak 1998; Hlušek et al. 2002a]. The production of one ton of garlic withdraws 2.80 kg of nitrogen and 0.80 kg of sulphur from the soil, the highest demands for sulphur of all bulbous plants [Hlušek et al. 2002b]. The cycling of sulphur and its use in plants is often compared to nitrogen because in soils it is oxidation that takes place, while in plants it is reduction [Vaněk et al. 2001]. Schnug [1993] states that insufficient sulphur nutrition causes poorer utilisation of nitrogen, which may eventually reduce the yields.

Plants take up sulphur from the soil solution particularly in the form of sulphates (SO_4) [Marschner 1995]; after reduction in the plant it enters various primary and secondary compounds, such as cysteine, methionine or essential oils of the alliin and allicin type [Haneklaus et al. 1997]. Other compounds which contain sulphur are e.g. tripeptide eglutathion (antioxidant and precursor of phytochelatins, which are also able to detoxify some heavy metals), ferredoxin, sulpholipids, glucosinolates, nitritreductase, vitamins B_1 and H and others [Schubert 2002]. Methionine and cysteine are essential amino acids. They are therefore irreplaceable components of proteins – their bonds play an important part in the structure of proteins, where they often form intra- or inter-chain disulfide bridges [Vaněk et al. 2001].

Not only are secondary S-metabolites valuable nutritionally, but they are also important in terms of the resistance of vegetables to diseases and pests [Schnug 1990].

According to Paulsen [2001], the sulphur components in onion of the Isoalliin, Cycloalliin, Thiosulfinate and Sulfinyldisulfide types are seen to have very positive effects on human health. They help digestion, they are anti-anaemic and anti-asthmatic and they are responsible for the specific aroma and pungency of onion.

The concentration of nitrates in vegetables is an important qualitative criterion; sulphur being a component of the enzyme nitrite reductase, which is responsible for the reduction of NO_2 in chloroplasts [Vetter 1988]. Sulphur deficiency also increases the risk that the levels of non-protein nitrogen in the plants will increase, in this number the content of nitrates; after reduction to nitrites they block the ability of haemoglobin to transfer oxygen in the human organism or they are a pre-stage to carcinogenic nitrosamines [Paulsen 2001]. The content of nitrates in plants is affected by the vegetable species, the level of nitrogenous fertilization, which part of the plant is analysed, the stage of growth and concentration of sulphur in tissues. At the same time a negative linear correlation was discovered between the nitrate concentrations in tissues and sulphur concentrations in plants. In 19 vegetable samples it was proved that NO_3 content decreased with increasing sulphur content [Zhang et al. 2001]. Nitrogen fertilisation of vegetables in terms of higher nitrate content in dependence on the N dose and external conditions is frequently affected by a number of external factors [Maynard et al. 1976].

The objective of establishing a vegetative pot trial with garlic was to evaluate the effect of three graded levels of sulphur in the soil under constant nitrogen nutrition on garlic yields and content of nitrates.

Methods

The vegetative pot trial with garlic was established in the spring of 2004 in the vegetation hall of the Department of Agrochemistry and Plant Nutrition, Mendel University of Agriculture and Forestry in Brno. Mitscherlich's vegetation pots were filled with 6 kg of medium heavy fluvial soil.

Table 1. Agrochemical characteristics of the soil

pH_{KCl}	According to Mehlich III method				$S\text{-}SO_4$
	P	K	Ca	Mg	
	mg kg^{-1}				
5.85	103	239	3769	366	18.3

Available elements were extracted from the soil according to Mehlich III method. The phosphorus content in the extract was determined using colorimetric method and potassium, magnesium and calcium – by atomic absorption spectrophotometry (AAS). Sulphate sulphur was extracted with demineralised water in a 1:5 ratio for 16 hours according to the ČSN ISO 11048. Capillary zone electrophoresis was applied for the measurement carried out in the accredited laboratory of the Central Institute for Supervising and testing in Agriculture (ÚKZÚZ) Brno on the CES-1 apparatus (Dionex Corp., USA) with a quartz capillary. The hydrogen ions activity (pH) was measured in a soil extract of 0.2 M KCl using potentiometric method. The soil showed a weak acid soil reaction, the contents of accessible phosphorus and potassium were on the level of good supply; the calcium content was high and that of magnesium very high (Table 1). The pattern of the experiment is shown in Table 2.

Table 2. Scheme of experiment

Treatment number	Pattern of fertilisation	Nutrient level	
		N (g pot^{-1})	S (mg kg^{-1})
1	N_1S_0	0.6	18.3
2	N_1S_1	0.6	40.0
3	N_1S_2	0.6	60.0

In variants 2 and 3 we increased the content of sulphate sulphur to the required level with applications of ammonium sulphate (20.5% N and 24% S). In all treatments nitrogen was equalized to a uniform level of 0.6 g N per pot (N_1) in the form of ammonium nitrate (34.5% N). On April 14, 2004 both fertilizers were applied to the pots in the form of watering one week prior to garlic planting. Four cloves of narrow-leaved spring giant garlic, variety 'Prim', were planted into each pot.

The experiment included 3 treatments; each was repeated 4 times. During vegetation the pots were watered with de-mineralised water on a regular basis to 60% of the maximal capillary capacity, the soil was loosened, kept free of weeds and the insecticide Sumithion against *Suillia lurida* was applied. The plants were harvested in the stage of full maturity on July 15, 2004. The amount of yield per pot and content of nitrate (mg NO_3 kg^{-1}) were evaluated.

Nitrates were determined in green plants by direct potentiometry using the ion-selective electrode. The yields were evaluated statistically by variance analysis specifying the minimal significant differences (LSD) at reliability 95, or 99%.

RESULTS

Yields of the experiment are shown in Table 3.

Table 3. Yielding of garlic in pot experiment

Variant	Pattern	Garlic yields		Nitrate contents (NO_3)	
		g pot^{-1}	Relative number %	mg NO_3 kg^{-1}	Relative number %
1	N_1S_0	24.96	100	385.3	100
2	N_1S_1	25.92	103.8	349.0	90.5
3	N_1S_2	27.40	109.8	298.0	77.3
$LSD_{0.05}$		1.43		21.3	
$LSD_{0.01}$		2.33		29.1	

It is apparent that the result of the increased level of soil sulphate sulphur to 60 mg S-SO_4 kg^{-1} (var. 3) was a 9.8% increase in garlic yields, which is statistically highly significant when compared to the control variant (var. 1), and statistically significant increase in yields by 6% compared to the lower level of sulphur in the soil (var. 2). There were no significant differences between variants 1 and 2. These results correspond to the conclusions of Hlušek et al. [1999], who discovered a 29% increase in onion yields after the application of 25 kg S ha^{-1} in ammonium sulphate. Likewise Zhang et al. [2003] found that the effect of combined applications of nitrogen and sulphur in 8 vegetable species was positive, the highest dose of S not always corresponding to the highest yield. Smatanová et al. [2004] noted increased yields of spinach after applications of 0.6 g N per pot and 30.6 mg S kg^{-1} in the soil by 54.1%.

The reduction of concentrations of undesirable nitrates in edible parts of garlic (Tab. 3) after sulphur applications was highly significant ($P_{0.01}$), i.e. by 9.5 % (var. 2) to 22.7 % (var. 3) compared to var. 1; in no variant was the permitted limited according to the Regulations of the Ministry of Health No. 53/2002 Sb exceeded. These results correspond to the findings of Smatanová et al. [2004], who noted a 44.1% decrease in the concentration of nitrates in red pepper when the sulphur content in soil increased to 30.6 mg S kg^{-1}. Likewise, Schnug [1990] discovered that the nitrate content in vegetable tissues increased under acute sulphur deficiency.

CONCLUSIONS

In a vegetation pot trial with garlic the positive effect of sulphur fertilization on garlic yields and quality was proved. Under the influence of the higher dose of sulphur the yields increased statistically significant by 9.8% compared with the control variant and by 6% compared to the lower dose of sulphur. With increasing sulphur dosages the reduction of nitrates contents in edible parts of garlic was highly significant, by 9.5 to 22.7% compared to the control treatment. The permitted limit of nitrates concentrations according to the Ministry of Health Regulations No. 53/2002 Sb was not exceeded in any variant.

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