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Macroscopic Symptomatology of Sulfur Deficiency Symptoms in *Brassica napus*

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S u m m a r y

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Occurrence of severe sulfur deficiency symptoms under field conditions is a major problem in *Brassica napus* (oilseed rape) cropping in Northern Europe. The decline of sulfur emissions due to effective desulfurization of fumes and simultaneous introduction of varieties with low glucosinolate contents and higher sensitivity towards insufficient sulfur supply are the main factors for macroscopic sulfur deficiency symptoms in *Brassica napus* species.

Symptomatology of sulfur deficiency is described for vegetative and generative plant parts in detail while pictorial documentation is given in SCHNUG & HANEKLAUS 1992.

I n t r o d u c t i o n

Severe sulfur deficiency is already one of the most frequent nutrient deficiency in Northern Europe arable agriculture. The reason for this is the significant reduction in atmospherical sulfur inputs to agricultural ecosystems due to limited emissions from oil and coal burning during the last decade. Additionally varieties with a genetically low content of glucosinolates show increased sensitivity to sulfur deficiency due to their less efficient metabolic use of sulfur (SCHNUG 1989). Severe sulfur deficiency symptoms occur, if total sulfur concentrations remain under 3.5 mg g dry weight^{-1} and collapse of the plant occurs below 2 mg g dry weight^{-1}. For optimum seed yield total sulfur concentrations of 6.5 mg g dry weight^{-1} are necessary (SCHNUG 1988). The nutritional status of *Brassica napus* plants can easily be determined by total sulfur determination of vegetative plant material -

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younger, fully differentiated leaves of the upper third of the canopy (cp. HANEKLAUS & SCHNUG 1991) - whereas determination of sulfate concentrations is not suited, because they are highly changeable.

From severe sulfur deficiency an inevitable environmental problem arises: As protein biosynthesis is handicapped nitrate cannot be bound to proteins, but is stored as undesirable free nitrate, which will lower food quality in case of vegetables. Moreover only reduced amounts of soil nitrate are utilized by sulfur deficient plants, so that losses of nitrogen are raised.

It should also be mentioned that steadily decreasing sulfur emissions already have led to severe sulfur deficiency symptoms in cereals and hints exist that damages of forests also partly account to insufficient sulfur supply. Therefore systematic studies on sulfur deficiency symptoms and their physiological effects will be necessary in order to face new environmental circumstances.

Commonly sulfur deficiency symptoms are believed to be less specific, but have not been described in detail for *Brassica* species so far. The contribution presents a comprehensive description of the symptomatology of sulfur deficiency in *Brassica napus*.

Foliar symptoms of sulfur deficiency

Foliar symptoms of sulfur deficiency may already occur in the very early development of young *Brassica* plants. As sulfate shows a very low mobility within the plants deficiency symptoms can first be observed at the younger leaves, which show a green-yellow colour in comparison to the green-blue of normal plants. Petioles are thinner, leaf size smaller and habitus reveals stiff appearance.

Chlorosis always starts from the outer periphery of the leaves, but the tissue around veins remain green even under severe sulfur deficiency conditions. The reason for this green remaining areas could be tracked back mainly to less intercellular space and thus a shorter and more effective transport of sulfate.

Sensitivity of sulfur deficient leaves to diseases (e.g. light leaf spot & phoma) is increased as an important natural defence mechanism via glucosinolates cannot become active in *Brassica napus* species low in glucosinolates (SCHNUG & CEYNOWA 1991). It can be proceeded that repellent effects of glucosinolates or their breakdown products are dependent on their concentrations in the plant cell. Under sulfur deficiency conditions, however, production of sulfur containing secondary plant metabolism products is obviously reduced and thus plant vigour extremely lowered.

Leaves of sulfur deficient *Brassica napus* plants show a characteristic marbling in combination with leaf deformation. They appear together with accumulation of anthocyanes. Enrichments of anthocyanes are not only typical of sulfur deficiency, but in principal secondary symptoms of essential nutrient deficiency (BUSSLER 1978). The earlier sulfur deficiency affects plant growth the more severe morphological changes - leaves bend inwards, so that spoon like deformities arise - can be observed. Moreover sulfur deficient *Brassica* plants give a succulent ap-

pearance. SCHNUG 1988 showed that enhanced chlorine uptake cannot cause these symptoms as there is no clear correlation between reduced sulfate and enhanced chlorine uptake. The effect is probably of mechanical nature with a reduced cell growth at leaf edges, while cell division around veins keep constant.

Flower symptoms of sulfur deficiency

A characteristic symptom of sulfur deficiency is the change of colour of flowers from yellow to white in combination with significantly reduced petal size, when sulfur deficiency starts early in vegetation period. Remarkable is moreover the egg-shape of sulfur deficient petals. Fertility is not negatively influenced by sulfur deficiency though their longevity is reduced on average from 2-3 days to one day and pollen production is strongly restricted.

The physiological background for this striking feature white flowering of *Brassica napus* may be explained as follows: In comparison with flavone production - responsible for the yellow colour of flowers- building of colourless anthocyanes is enhanced in order to bind increased carbohydrates resulting from insufficient sulfate concentrations in plant cells. Consequently the enrichment of colourless anthocyanes is accompanied by switching the colour of flowers from yellow to white. Genetic reasons for this symptom can be excluded as according to physiological sulfate status in single flowers both yellow and white flowers are developed side by side. Moreover it is possible to switch white flowering *Brassica napus* to yellow by sulfate applications.

Maturity symptoms of sulfur deficiency

Due to severe sulfur deficiency pod number and size of *Brassica napus* plants is markedly reduced together with seed number, while Thousand Grain Weight is less affected. Under conditions of severe sulfur deficiency not more than 1 - 3 seeds pod^{-1} are formed, while normally 15 - 20 seeds pod^{-1} are developed. Morphological deformities of pods commonly described as "rubber pods" are manifested as follows: siliques are pale green, often in combination with anthocyane enrichments and compressed so that they have a succulent appearance. In practical agriculture loss of yield due to sulfur deficiency reaches values of more then 50% (BOOTH & al. 1991, PEDERSEN 1992).

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