SULPHUR SUPPLY AND STRESS RESISTANCE IN OILSEED RAPE

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ABSTRACT

The sulphur (S) metabolism of oilseed rape plants provides several mechanisms by which plants are able to tackle with abiotic and biotic stress. The intensity of these mechanisms are closely related to the S status of plants and may be enhanced by applying S fertilisers to the crop. This contribution will provide a brief overview about relevant biochemical pathways (H_2S-release, glutathione-, phytochelatine-, glucosinolate-, phytoalexine-, glucosinolate- and S rich protein synthesis) and investigate their significance for stress resistance. Furthermore the challenges of stimulating these mechanisms by S fertilisation for sustainable oilseed rape production will be highlighted.

INTRODUCTION

Sulphur (S) has long been known for its protective effects for plants against pest and disease. Most of the knowledge is, however, restricted to the external effects of foliar applied S. Less is known about soil supplied S which has a strong influence on plant resistance by stimulating directly biochemical processes in the primary and secondary metabolism. An example from field trials on an S deficient site in Scotland is given in figure 1, where a disease resistant and a non-resistant oilseed rape (OSR) variety were treated with soil applied S and a foliar applied fungicide. The non resistant variety shows a much stronger response to the fungicide under S deficiency than the resistant variety does. Other examples are the regional abundance of the light leaf spot disease which proliferates much faster in S deficient environments (Schnug and Ceynowa, 1990). All this indicates clearly some special interaction of the S supply with plant health but as with with many other reports on beneficial effects of S fertilisation on crop health (e.g. Pedersen, 1990; Walker and Booth, 1994) the result do not indicate anything about causalities. The objective of this contribution is to give a very brief overview about relevant biochemical pathways soil absorbed S undergoes in the plant metabolism and which may influence the crop interaction with stress factors.

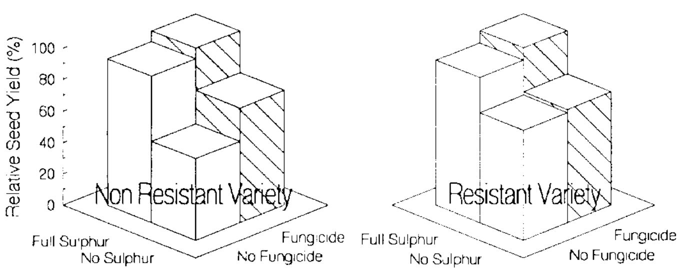

FIGURE 1. Effect of S and fungicides on yield of two OSR varieties

PATHWAYS PRIOR TO AMINO ACID BIOSYNTHESIS

Release of volatile S compounds (VSC): The primary metabolism of S begins with the reduction of sulphate, which is the major S compound absorbed by plant roots from the soil. During the reduction significant amounts of S are released to the atmosphere of which H_2S is the predominant form followed by dimethylsulphide (Schroeder, 1994). The losses of VSC's to the atmosphere, which for crops, shall amount according to literature to 2-3 kg/ha*y, are proportional to the S supply and are recently only understood as a regulatory step in order to level the S pools in the plants (Schroeder, 1994). However, an important but so far neglected effect of gaseous S emissions from plants is their significant toxic activity against fungal attacks on the leaf surface. Therefore it is likely that the flush of H_2S during uptake and reduction of soil applied S helps the plant to combat fungal attacks. An indirect effect of the release of reduced VSC's could be their reaction with surface ozone (Schnug and Haneklaus, 1994) by which oxidative stress would be lowered even outside the organism.

PATHWAYS AFTER AMINO ACID BIOSYNTHESIS

Glutathione synthesis: glutathione (GSH) (γ-glutamyl-cysteinyl-glycine) is a S containing compound of the primary metabolism which is synthesised in a two step reaction from cysteine, glutamate and glycine (Bergmann and Rennenberg, 1993). GSH is the major free low molecular non-protein thiol compound in the plant. It not only plays a role in storage and distribution of reduced S in plants but it is also known as an essential component of the plant's defence system for instance against oxidative stress and for the detoxification of xenobiotics (Rennenberg and Brunold, 1994). The positive effect of GSH on drought-, chilling- and freezing resistance, however, is still questioned (Kok and Stulen, 1993). The S supply of OSR is a major factor maintaining the GSH content of OSR (Schnug et al., 1995). S deficient plants have very low GSH concentrations whereas S fertilisation strongly increases the free thiol content. Thus S deficient plants are more vulnerable to stress factors which are normally compensated by the GSH system and so S fertilisation should have a positive effect on resistance mechanisms provided by the GSH pathways.

Phytochelatine synthesis: phytochelatines (PC) (poly $(\gamma\text{-glutamyl-cysteinyl})_n$-glycines; n=2-8) are synthesised from glutathione by plants under heavy metal stress (Rennenberg and Brunold, 1994). The elements Ag, As, Bi, Cd, Cu, Pb and Zn have been shown to induce the synthesis of these compounds (Grill et al., 1993). Heavy metal stress is an increasing problem for plants because metal loads in soils are continuously being raised due to the increasing recycling of wastes and sludges in agriculture and by long term fertilising with phosphates. By producing PC's plants not only protect themselves against heavy metal stress but also prevent them from entering the food chain. Because the production of the precursor (GSH) is dependent on the S status it is likely that this mechanism is dependent on the S status too. Thus S deficient plants may not be able to produce PC's under heavy metal stress and vice versa S fertilisation may fortify the production of PC's and strengthen the resistance of the plants.

Glucosinolate synthesis: glucosinolates (GSL) are characteristically S containing compounds of the secondary metabolism of OSR. Their basic structure is synthesised from α-aminoacids by glucosylation and sulphatation and their probably most important ecological function is to act as a storage for S via an enzymatic recycling (Schnug, 1993). There has been much speculations about role of GSL's in the plant's defence system against pests and disease (Ernst, 1993; Schnug and Ceynowa, 1990). As the GSL content is positively influenced by an increasing S supply, stress mechanisms attributed to GSL are enhanced too.

Phytoalexin synthesis: the S containing phytoalexins (PA) of the brassinin family are synthesised as stress metabolites in OSR by cyclisation of the thiocyanate moiety from indolglucosinolates following microbial infections or abiotic stress attacks (Gross, 1993). Recently these compounds are understood as defence chemicals. Their dependency upon the S supply may be speculated from the dependency on S of their precursors.

PATHWAYS AFTER PROTEIN BIOSYNTHESIS

Synthesis of S rich proteins (SRP): enzyme inhibitors (e.g. of the Bowman-Birk family), lectins, thionins and γ-thionins are all cysteine rich proteins which are identified in several plant groups and seem to be part of the plant´s defence system because they show a high toxicity against micro-organisms, insects and mammals. The first two groups of SRP´s are usually pre-synthesised, whereas the thionins seem to be newly synthesised after biotic stress attack (Bohlmann, 1993). Up to now research in this field did not involve *Brassica* species but there is no doubt that this SRP´s are also abundant in this genus. From the already known relationship with common protein bodies an influence of the S supply on quality and quantity of SRP´s can be assumed which, however, still requires empirical proof.

CONCLUSIONS

This overview reveal that S is a plant nutrient which is in many ways involved in the plant´s defence system against pests and disease. There is strong evidence that in many cases weakened stress resistance of OSR may be worsened by an insufficient S supply due to the reduction of atmospheric S depositions to agroecosystems (Schnug and Haneklaus, 1994). However, there is the challenge of using S fertilisation to improve plant health which would help to reduce chemical inputs and move towards sustainable OSR production.

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