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SULPHUR DEFICIENCY IN OILSEED RAPE FLOWERS - SYMPTOMATOLOGY, BIOCHEMISTRY AND ECOLOGICAL IMPACT

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ABSTRACT

Symptoms of severe sulphur (S) deficiency can be observed at all growth stages of oilseed rape. They are most likely if the concentration in fully developed younger leaves drops below 3.5 mg/g S. S deficiency is the only nutrient disorder which shows symptoms on flowers. Symptom expression under S stress is strongly dependent on the photosynthetic activity and thus on general growth conditions. Disorders in shape and colour of flowers are fairly often misinterpreted as an indication of genetic instability in oilseed rape lines and therefore knowledge about environmental factors affecting the appearance of rapeseed flowers is of great importance for rapeseed breeders. However, with prospect of hybrid OSR introduction, there is increasing interest in the relationship between S nutritional status, flower ecology and pollinating biocoenosis. This paper presents the biochemical background of ´white flowering´ and its physiological and ecological impact.

INTRODUCTION

Due to significant reductions in atmospheric sulphur (S) depositions, S deficiency is now the major nutrient disorder in European oilseed rape cropping. The symptomatology of severe S deficiency in oilseed rape is impressive, and characteristic symptoms can be observed throughout the vegetative period. Symptoms are most likely if the concentration of S in the dry matter of fully developed leaves drop below 3.5 mg/g. A detailed description of S deficiency in oilseed rape, together with coloured photographs is given by Schnug and Haneklaus (1994). One very special feature of S deficiency in oilseed rape is that it results in typical disorders in shape and colour of flowers (Schnug and Haneklaus 1994). Breeders, however, may believe these features are genetically stable parameters and use them to check variety purity. It is the objective of the paper to highlight S as an environmental factor which influences the appearance of rapeseed flowers. The biochemical background of the phenomenon and its physiological and ecological impacts are also discussed.

DISORDERS IN PETAL COLOUR

One of the most fascinating phenomena in the symptomatology of nutrient deficiency is the "white flowering" of S deficient oilseed rape plants (Fig. 1, Haneklaus and Schnug 1994). This symptom is often overlooked in the field, because human eyes need at least 10-15 minutes to adapt for the recognition of white flowers within a full blooming rapeseed field. The trigger for the colour change is most likely the increasing sugar concentrations in the tissue due to disorders in protein metabolism. By pigment formation, plants prevent excessive accumulations of free sugars. Thus, white flowering in S deficient crops is most likely to occur during periods of high photosynthetic activity. For the phenomenon to occur, two mechanisms could be involved: One major pigment causing the yellow colour of rapeseed flowers is the flavonol quercetagetin and its isorhamnetin 3-glycoside (Harborne 1967). Glycosylation of flavonols, however, has a hypsochromic effect which might shift the absorption spectra to the UV range which is invisible for human eyes. The second hypothesis is that the increasing sugar concentrations promote the formation of anthocyanines which would occur in a form of colourless leucoanthocyanines. Like any other S deficient tissue of oilseed rape, white petals show lower cysteine, γ-glutamyl cysteine, glutathione and ascorbate concentrations but increased peroxidase activity (Schnug et al 1995).

DISORDERS IN PETAL SHAPE

Depending on the duration of S deficiency not only the colour but also the size and shape of oilseed rape flowers are affected. Breakdowns of the S supply within a short time are the reason for white but normal shaped petals. This phenomenon is typical for sites where S deficiency due to decreasing environmental S inputs are just beginning to develop. In regions with an established low S input, such as in all northern European growing areas, S deficient white rapeseed flowers are significantly smaller with more oval shaped petals (Fig. 2). At the same time white rapeseed flowers show a significantly higher variability in their size (Fig. 2).

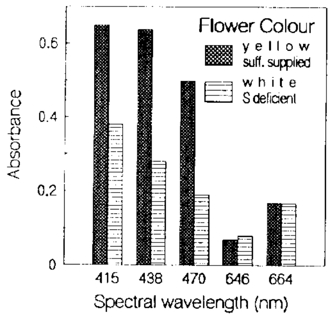

FIGURE 1.
Absorption Spectra of Rapeseed Flowers
(50mg freeze dried petal material in 10ml 80% acetone)

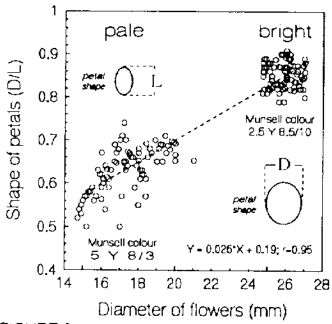

FIGURE 2.
Shape and Colour of Rapeseed Flowers and Petals

PHYSIOLOGICAL AND ECOLOGICAL SIGNIFICANCE OF FLOWER SYMPTOMS CAUSED BY S DEFICIENCY IN OILSEED RAPE

The fertility of S starving flowers is not obviously affected. But if any pods develop from white flowers, they are small with significantly reduced numbers of seeds, with seed production sometimes reduced to zero (Schnug and Haneklaus 1994).

Seeds developed on S starving oilseed rape plants are vulnerable to early germination in the pods prior to harvest, especially under humid conditions and when the harvest is delayed. The hypothesis explaining this phenomenon is the increased anthocyanine production under S stress (Schnug and Haneklaus 1994) which again has a stimulating effect on indolacetic acid oxidase (Stenlid 1963). The resulting increase in indolacetic acid activity than may cause an early breakdown of seed dormancy.

The bright yellow colour of blooming rapeseed fields is very attractive to honey bees and oilseed rape is by far the most important agricultural crop providing forage for honey bees. Crops visited by bees show earlier petal fall probably because they set more early flowers resulting in more uniform pod ripening and ease of harvesting which may end up in higher harvested yields (Williams and Cook 1982). Nectar, however, is the carbohydrate fuel for flight of bees whose hovering is the most energy expensive form of flight. It is important to realise that for a 'cold' take off the bee consumes relatively vast amounts of energy. Compared to civil aviation this is equivalent the fuel load a Jumbo-Jet would use for a whole transatlantic flight. To maintain operation it is vital for the bee to refuel on each flower visited and especially to avoid visiting flowers where the nectar reservoir has already been emptied by a colleague. The reflective pattern of flowers provides flower visitors with clues as to the age of the flowers and presence of food rewards (Kevan and Baker, 1983), but bees are also influenced by the shapes, outline forms, and outline lengths of flowers (Leppik, 1956). During senescence of rapeseed flowers, which starts immediately after pollination, the yellow petal colour vanishes and the petals shrink quickly before falling to ground. A pollinated and fading rapeseed flower looks very similar to an unpollinated but S deficient one. Thus it is obvious that the visual message the bee receives from a S deficient rapeseed flower is that of an already visited one with an emptied nectarium. Barth (1982) reported that bees definitively prefer yellow flowers before white ones and from our own research we know that in S deficient fields much lower bee activity is observed than in S sufficient crops which are bright yellow. In terms of pollination this may be of minor interest in common rapeseed varieties which are highly self pollinating. However, the introduction of rapeseed hybrids where female and male plants need to grow side by side together is much more dependent upon pollination by bees. First observations in field grown hybrides show increased problems with pollination of hybrides in low sulphur environments which can be attributed to the processes discussed above,

CONCLUSIONS

Although the general impacts are obvious there are still a lot more details to investigate. In particular, the role of flavonoids for the phytohormonal regulation of rapeseed plants and its relationship to the nutritional status could be of significant practical interest. The introduction of oilseed rape hybrides with a high dependency upon pollinators will highlight the need for a better understanding of the processes. But in any case, S deficiency in oilseed rape and especially its influence on flowers and biocoenosis presents a fine example of how difficult the maintenance of ecosystems by man is. Who could have imagined in the beginning of the 80´s that the honourable idea of reducing the SO_2 emissions from burning fossil fuels (Sendner 1985) would have an impact on honey production twenty years later?

REFERENCES

Barth, F. G. (1982): Biologie einer Begegnung. *DVA Stuttgart.*

Brouillard, R. (1988): Flavonoids and flower colour. In: *Harborne, J. B. (ed.) The flavonoids. Chapman and Hall Ltd. London.*

Haneklaus, S. and Schnug, E. (1994): Oilseed rape / Sulphur. *The Sulphur Institute Washington.*

Harborne, J. B. (1967): Comparable biochemistry of the flavonoids. *Academic Press London.*

Schnug, E. and Haneklaus, S. (1994): Sulphur deficiency in *Brassica napus* - biochemistry, symptomatology, morphogenesis. *Landbauforschung Voelkenrode* **Sonderheft 144.**

Schnug, E. Haneklaus, S., Borchers, A. and Polle, A. (1995): Relations between sulphur supply and glutathione, ascorbate and glucosinolate concentrations in *Brassica napus* varieties. *J. Plant Nutr. Soil Sci.* (in press).

Sendner, H. (1985): Der 30% Club. *Unsere Umwelt: Wald* **1**, 12-19

Stenlid, G. (1963): The effects of flavonoid compounds on oxidative phosphorylation and on the enzymatic destruction of indolacetic acid. *Physiologia Plantarum* **16**, 110-120.

Kevan, P. G. and Baker, H. G. (1983): Insects as flower visitors and polinators. *Ann. Rev. Entomol.* **28**, 407-453.

Leppik, E. E. (1956): The form and function of numerical pattern in flowers. *Amer. J. Bot.* **43**, 445-455.

Williams, I. H., and Cook, V. A. (1982): The beekeeping potential of oilseed rape. *British Beekeepers Ass. Stoneleigh*