NOTE ABOUT SULPHUR FERTILIZATION OF WINTER RAPESEED

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ABSTRACT

Plant nutrition management needs parameters like requirements (absorption curves), sensitivity to deficiency at different growth stages, soil residues, etc... All those parameters (mainly the soil ones) are difficult to check, especially for minor or micronutrients. Interactions between soil/climate/crop growth need also to be taken into account. The paper deals with examples of tools available to check sulphur nutrition of rapeseed crops. Sulphur requirements are high for rape and deficiencies induce losses in plant production. If leaf analysis could be useful to predict a risk of deficiency, very often, the information is too late (in spring) for the farmers. We tried to evaluate the useful criteria for earlier prediction: among them, we defined a method (Scott method) to check the S-residues in the soil, taking into account early in spring, not only the SO4 available for the crop, but also the part of S from the organic matter, susceptible to be mineralized in spring. A threshold of 18 ppm for S-Scott in the soil in spring had been defined as the limit below which yield losses would occur due to S-deficiencies. Examples of crop responses to sulphur application are presented and the effect on quality (i.e., glucosinolates) is also illustrated.

Key words: glucosinolate, fertilization, sulphur, winter rapeseed, yield quantity and quality.

INTRODUCTION

Sulphur is one of the elements required for the growth and development of winter rapeseed which deserve particular attention. The substantial needs of the plant are such that, for this crop, is should be considered on the same level as the other main elements. Furthermore, the repercussions of this cultivation process on the quality of the crop (glucosinolate content) and the necessity of reducing production input elements strongly emphasise the logic of this technique.

Plant requirements

Plant requirements are fairly low in the autumn and the quantities absorbed range between 20 and 30 kg of SO_3 per hectare. When growth resumes, the kinetics of the accumulation of dry matter goes hand in hand with that of the accumulation of sulphur. The total quantities mobilized by the plant vary between 180 and 200 units of SO_3 per hectare (SO_3 = 2.5 S). The main part of this absorption occurs between stage C_1 and stage G_2-G_3 (CETIOM-INRA-PV scale). When the crop is harvested, 60% of the quantity absorbed is restored to the soil (Merrien, 1989). There is considerable synergy between the absorption of sulphur and nitrogen. Compared with other crops, rapeseed definitely seems to require a fair amount of sulphur.

The total sulphur requirements of “00” varieties differ little from those of the old varieties. There is a different distribution of the sulphur compounds between the organs: at maturity, there is an identical quantity of sulphur in the pod walls and in the grain of the “0” varieties, whereas it can be clearly demonstrated that with the “00” varieties, there is a higher accumulation of these compounds in the pod walls and a lower content in the grain (Merrien, 1989 a; Schnug, 1989).

Deficiency

Symptoms presented by this crop are very typical which facilitates diagnosis. They can be described as follows (Merrien, 1987):

- Sulphur deficiency reduces the chlorophyll content causing the discolouration of the youngest leaves, the veins remaining green. This discolouration is whitish in colour, but in extreme cases, leaves become reddish. In this case, lack of nitrogen is frequently associated with a sulphur deficiency.
- Growth of the plant and production of dry matter is held back; there is a marked difference in flowering. During the maturity phase, the pods, the main organs that accumulate dry matter, again reveal this difference.
- When flowering occurs, discolouration of the petals is clearly evident (whitish colour) and arrested development leading to empty pods is significantly high. Table 1 illustrates perfectly the role the sulphur plays in the fertility of the pods. The significant effect on the total number of grains produced per plant if the dose of sulphur is reduced or cut out entirely can principally be explained by the

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Table 1. The effect of sulphur fertilization on the yied and its constituents

Nitrogen (kg N/ha) Sulphur (kg SO_3/ha)	240 60	240 30	240 0	0 60	0 30	Stat. analysis
Number of branches/plant	8	8.9	8	5.8	6	NS
Number of pods/plant	116	122	124	91	87	NS
Number of seeds/plant	1705	1171	1090	964	690	S
Number of seeds/pod	14.7	9.6	8.8	10.6	7.6	HS
1000-seed weight (g)	5.3	5.8	6	5.6	5.4	NS

NS = no significative diff.; S = significative diff.; HS = high significative difference

extremely significant effect on the average number of grains per pod.

These symptoms may all be fairly transient or not very pronounced but repercussions on production are considerable.

Climatic conditions play an important role in the risk of appearance of sulphur deficiencies. Alternate high and low temperatures, therefore, set off mineralization cycles and heavy rain causes leaching. Risks are higher when rainwater accumulated over the 4 winter months (Nov./Dec./Jan./Feb.) is over and above the 350 mm level.

It should also be noted that knowing the total sulphur content of the soil will not provide sufficiently accurate information to be able to provide adequate nutrition for the plant. In spring, the amount of S present will mainly depend on the rate of mineralization, the organic matter in the soil, temeprature, aeration of this soil, its texture and pH (Merrien, 1989 a).

MATERIALS AND METHODS

It has already been stated that the total quantity of sulphur present in soils cannot be considered a potential nutrition indicator for the plant. However, analytically speaking, use of the "Scott" method for determining the amount of sulphur in the soil does give cause for hope (Scott and Anderson, 1978). This allows us to simultaneously ascertain the sulphur present in the form of sulfates when the sample is taken and also the fraction of sulphur present in organic matter, likely to be liberated in the spring by means of mineralization.

Furthermore, there are less constraints as far as sample conservation conditions are concerned; the sample should, however, be protected from severe temperature fluctuations. Analysis is made on a dried soil sample in the open air. A 5 g sample is taken. An extraction reagent (500 ppm of P) is added. This is either KH_2PO_4 with active carbon added to eliminate organic suspension colloids, or $Ca(H_2PO_4)2$. The m/v extraction ratio is 1/10 (i.e.5 g to 50 ml). Agitation lasts for 30 minutes at 20°C. It is filtered and the amount of sulphur extracted is measured by emission spectrometry (inductive plasma torch).

We have tested the validity of this method to diagnose the risk of deficiency and obtain a reaction to fertilization by comparing a test plot with sulphur added at the C_2/D_1 stage (75u SO_3) to a control plot without sulphur, in a large number of situations (Merrien, 1990 a). Before adding sulphur, a Scott S content analysis was made on the 0-30cm layer. We used this process with the adjacent control. All in all, we compared 72 situations between 1988 and 1991. On average, taking all the situations into account, we obtained an increase in yield of 2.28q/ha by adding 75u of SO3 at the start of the growing period.

A few cases of acute deficiency can be observed where differences in yield between the control plot and the test plot rose to almost 10 q/ha, showing just how harmful this deficiency can be. The results (Figure 1) lead us to believe that below 18 mg/kg of S (measured by the Scott method) is limiting for the growth of rapeseed and the addition of sulphur is to be advocated. Above this amount, the quantities of sulphates and the potential mineralization of the soil are sufficient to cover the needs of the plant. Adding sulphur is not then justified.

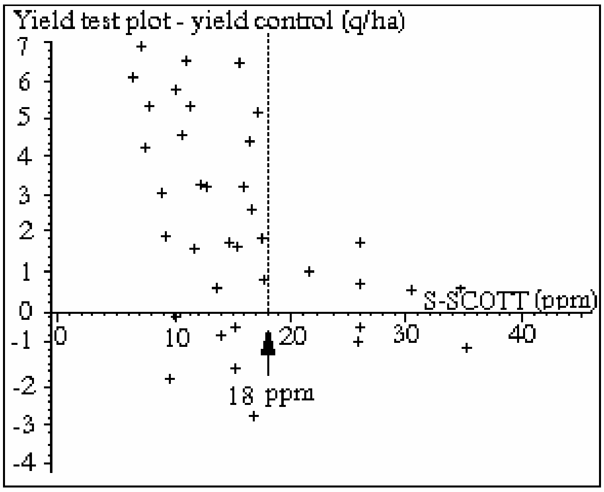

Figure 1. Relation between Scott S content at the end of the winter and an increase in yield following the addition of sulphur

Although the Scott sulphur measurement test at the start of the growing period does not by itself explain all the variances in yield, we can, however, confirm that this analytical tool can contribute to the efficient assessment of situations where reaction to adding sulphur is more than likely.

RESULTS AND DISCUSSIONS

Table 2 indicates the differences in yield according to the analytical value obtained. Forty-six situations (38+8) were classified: that is to say, the reaction to the addition of sulphur was predicted and observed for 38 of these; for 8 situations we predicted and observed that there was a negative reaction to the addition of sulphur, according to the analysis.

Table 2. Classification of the trials according to the S-Scott analysis prediction

	Diff. yield > 0	Diff. yield < 0	Diff. yield > 0	Diff. yield < 0
	S-Scott < 18 ppm		S-Scott > 18 ppm	
N	38	16	10	8
Delta (q/ha)	+4.77	- 1.15	+ 0.99	- 1.06

Contrary to this, 26 situations (16+10) were badly classified (contradictory results between the reaction predicted by the S-Scott test and the observed result). Among the situations correctly classified, an average increase in yield of + 4.77 q/ha was noted.

These results were obtained by adding the correct proportions at the C_2/D_1 stage in the growth cycle; it is rather late to intervene at this stage of growth. We have endeavoured to ascertain whether this value observed in spring showed any kind of significant fluctuation over time.

We were able to show:

→A reatively stable S content in the spring between January and May

→A gradual increase in content as temperatures rose at the end of spring.

→Rainfall strongly affects the final result of the analysis: April rains caused a probable leaching of the sulphates, leading to absorption by the plants. A clear drop in S content by could be observed in the fololowing 2 months.

→In the middle of summer, the increase in S content corresponds to a decrease in rainfall, temperatures that are favourable to the mineralization of the sulphur and absorption by the crop ceasing.

→The following autumn, a return to S contents close to those observed in the spring was noted, leading us to foresee the utilization of this method (and the 18 ppm threshold) to decide whether to use sulphur fertilization early enough in the growing cycle.

From these results, it would seem possible to predict with a probable success rate of 3 out of 4 whether a reaction would be obtained by adding sulphur, using this technique. However, treatment should be avoided during the summer or following a period of heavy rain.

Complementary studies carried out in the area of foliar diagnosis have enabled us to successfully complete the soil analysis tool (Merrien, 1990 b). The optimal content to be reached in rapeseed leaves at the D1 stage is between 0.5 and 0.7% of the dry matter (optimum is 0.53). These values are on the whole higher than those known for other varieties (0,20% for cereals) and confirm the importance of sulphur for the mineral fertilization of rapeseed.

From the experiment references gathered on figure 2 (10 trials), it seems clear that the addition of sulphur (75u of SO3 at the C_1/C_2 stage) generates an average gain of 3.43 q/ha. These figures mask variances that can reach 10 q. We can then find values close to those observed in figure 1.

As regards frequency, it seems that this practice is beneficial 8 out of ten years. It also appears that a double addition of sulphur does not generate a further increase in productivity, comparatively speaking. In practice, it can be noted that the addition of sulphur when growing rapeseed is profitable: improved measurement of the "Scott"method will doubtlessly be a first step towards justifying sulphur fertilization.

Figure 2 definitely confirms that the optimum reaction to the addition of sulphur in the spring is obtained with 75u to 100 u of SO_3 (Merrien, 1992).

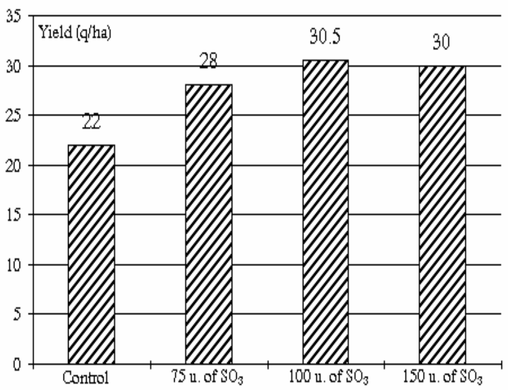

Figure 2. An example of the reaction to sulphur fertilization

Our results have never allowed us to pinpoint any special interest in fertilizing in autumn. When sulphur is added in the springtime, the actual date should be modulated due to climatic conditions that may immobilize the sulphur when temperatures are low. South of the Loire, sulphur can be added in February with the first nitrogen application. However, in the Northern regions, it is advisable to add the sulphur when nitrogen is added for the second time, at least that is when N-fertilization is carried out in two sessions. In any case, sulphur should not be added befor the end of February in the Northern regions. It is possible to correct the deficiency after the symptoms have appeared: swift action is necessary and 100 to 150 kg/ha of ammonium sulphate diluted in 500 l of water should be sprayed.

For several years now, it has been indicated that this sulphur fertilization could cause an increase in the content of sulphur compounds in the grain, particularly glucosinolates (GLS) (Merrien, 1989 b, Schnug, 1989).

During the industrial oil extraction process, deteriorating substances from these GLS can cause animals to lose their partiality to the cattle-cake produced. Goitre effects were also noticed.

The conversion from varieties of rapeseed without erucic acid ("0") to varieties with a low glucosinolate content ("00") has enabled substantial improvement in the quality of the crop. However, sulphur is a factor (albeit not the only one) which may increase the final GLS content of the grain and, therefore, diminish nutritional quality (Figure 3).

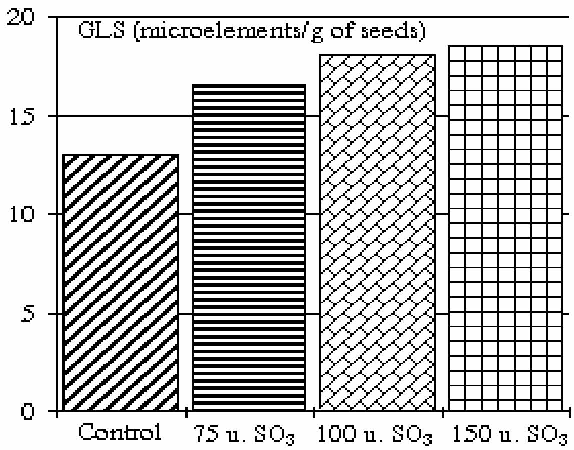

Figure 3. Impact of sulphur application on glucosinolates in the harvested seeds

Whereas sulphur requirements are more or less the same and the effect on yield similar, the final GLS content of the grain would appear less affected in varieties with a very low GLS content. This is fairly well explained by the differences in the transfer of sulphur compounds between the pod walls and the grain. In the case of the "0" varieties, transfer is less efficient and more sulphur accumulates in the pod walls which seem to constitute a barrier for the GLS.

These observations call for a few remarks concerning fertilization. A compromise has to be found between the quality and the quantity of the yield: a moderate dose of sulphur (between 70 and 80u of SO_3/ha) will provide this safeguard.

A productivity gain for rapeseed is obtained by an increase in the number of grains: it is, therefore, possible to achieve the two objectives simultaneously: optimize the yield (and the sulphur fertilization will help by protecting the potential number of grains) and satisfy quality requirements.

CONCLUSIONS

All of these results have significant practical implications, both as regards sulphur fertilization and the overall theories related to crop cultivation. Any factor that favours a high number of grain per square metre (we have seen above that sulphur contributes to this...) will also be favourable to the observance of market standards for GLS content and, above all, to the production of cattle-cake with improved nutritional value.

Today, due to the progress made by genetics, farmers have at their disposal varieties with a very low GLS content (less than 10 µmoles/g of seed) on which the influence of sulphur fertilizer on the quality will be proportionally relativized.

In view of these effects, it is important to count the actual quantities of sulphur used on the crop very accurately, taking careful account of the "hidden" forms that are applied with nitrogen fertilization (liquid nitrogen solutions, ammonium sulphate,...). The optimum agronomic amount of sulphur to be added to a rapeseed crop under French conditions is around 75u of SO_3 per hectare. This proportion will avoid loss of yield due to arrested grain development. The negative effect on the quality of the grain will also be limited.

In more general terms, it is important to identify risk situations (or excess situations). The tools available can be summed up as follows:

- Knowledge of the total winter rainfall (11/12/01/02): over and above an accumulation of 350 mm, winter leaching strongly increases the risk of sulphur deficiency and the addition of sulphur is advisable and will probably be beneficial.

- It is possible to know the quantity of sulphur present in the soil (amount present at a given time "t" in the form of SO_4, together with the mineralization potential) by means of the "Scott" method. Our trials have indicated an intervention level at 18 mg/kg. Testing can be carried out at the end of winter before fertilization.

The approximate cost of one analysis is FF 50.

- Analysis of plants (foliar diagnosis technique) has also indicated that optimal feeding of plants is ensured if the limbs contain 0.53 ppm at the D_1 stage in the growing cycle. However, this sort of analysis is expensive (approx. FF 350 for a complete foliar diagnosis) and often too late for decision of S application. Nevertheless, this information could be obtained to identify sulfur deficiencies on crops during the growing cycle.

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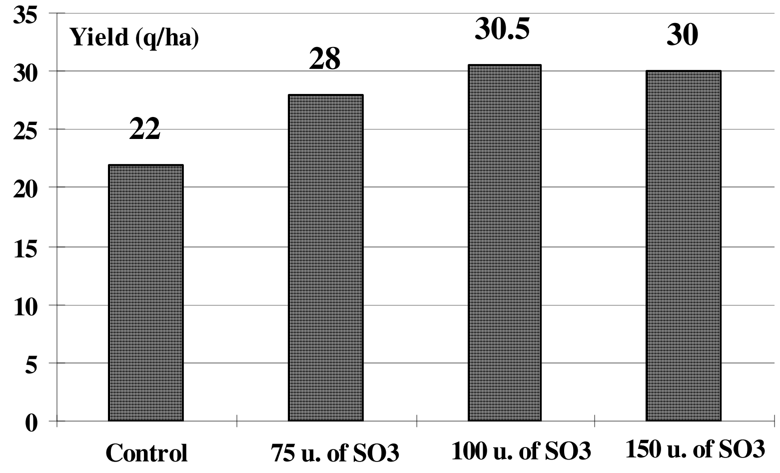

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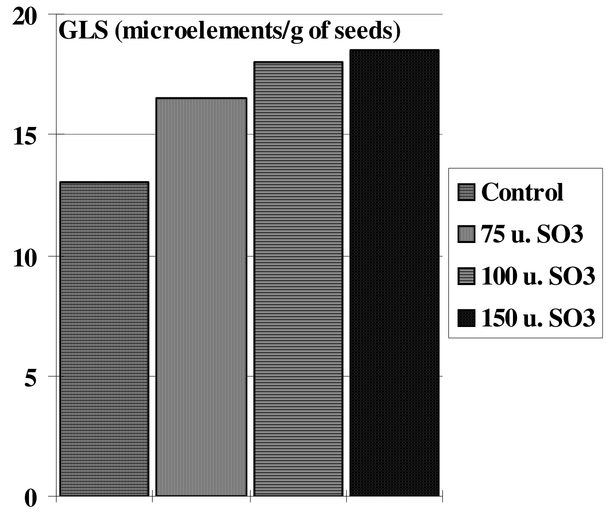

Figure 3 **:** Impacts of sulphur application on glucosinolates in the harvested seeds.