How about some Sulfur?

SULFUR MATTERS

Sulfur is one of the 6 main nutrients for crop growth. It is an essential part of amino acids, co-enzymes and vitamins. Protein content and quality of crops rely on sufficient supply of sulfur. Since environmental measures have improved air quality in industrialized countries, depositions of sulfur have dropped. At the same time, yield and quality expectations have increased. Both factors together account for the rising attention to sulfur fertilization in the last decade.

This pure nutrient fact is dedicated to the questions of sulfur management in modern fertilization practice.

YARA

Knowledge grows

Sulfurous – **but essential**

Sulfur, as nitrogen, is a vital ingredient of life. Often linked to each other in biological processes, both elements form an inseparable team. In agriculture, however, dominated by the questions about nitrogen fertilization, sulfur was confined to a second role. Today, sulfur is reconsidered at its rightful place: an essential nutrient and counterpart for optimum nitrogen efficiency.

WHY SULFUR?

Sulfur is a fundamental ingredient of life on earth. It is present through different forms:

- As elementary sulfur (S), sulfite (SO_3^{2-}), sulfate (SO_4^{2-}) and pyrite (FeS) in the soil.
- As hydrogenated sulfur (H_2S) and sulfur dioxide (SO_2) in the atmosphere.
- As sulfate (SO_4^{2-}) in the oceans.

Elementary sulfur is not immediately available to plants and needs to be mineralized first. Sulfur is present in all crops and plays an important role in plant metabolism. It is one of the 6 most important nutrients.

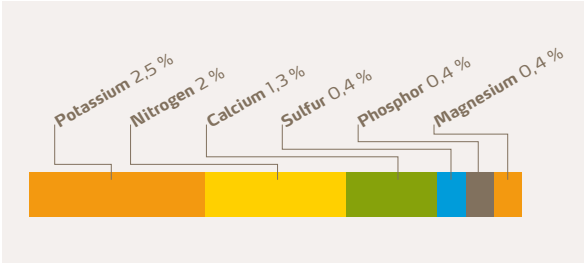


Figure 1: Sulfur ranks amongst the 6 most important nutrients in plants.

SULFUR STANDS FOR QUALITY

Most compounds containing sulfur also contain nitrogen, thus highlighting the close link between these two elements. Sulfur is part of an enzyme required for nitrogen uptake and lack of sulfur can severely hamper nitrogen metabolism. Together with nitrogen, sulfur enables formation of amino acids needed for protein synthesis. It is found in fatty acids and vitamins and has an important impact on quality and organoleptic properties of crops. Sulfur is also essentially involved in photosynthesis, overall energy metabolism and carbohydrate production.

Some cruciferous forages (e.g. rapeseed) use significant proportions of sulfur. Garlic and onions need sulfur to produce allins. Both secondary plant substances have a determining impact on odor and taste, but also improve plant resistance and self-defense. In leguminous, sulfur is needed for fixation of nitrogen from the air.

SULFUR DEFICIENCY - OFTEN NEGLECTED

Until the 90s, sulfur availability was not a matter of concern since sulfur dioxide emissions from industrial origins guaranteed a sufficient and automatic supply. Environmental regulation in general and low sulfur fuel in particular has strongly reduced such emissions. At the same time, higher yield and quality expectations have increased sulfur withdrawal from the field. If sulfur deficiencies were fairly rare 20 years ago, they are commonly encountered today.

Sulfur deficiencies are more likely to occur under the following conditions:

- Light and sandy soils with little soil organic matter (>low sulfur content)
- High precipitations during winter (> sulfur leaching)
- Dry spring (> low mobility of sulfates)
- Low temperature (> low mineralization rate)
- Low input of organic matter and mineral sulfur(> low input)
- Distance from industrial sites (> low depositions)

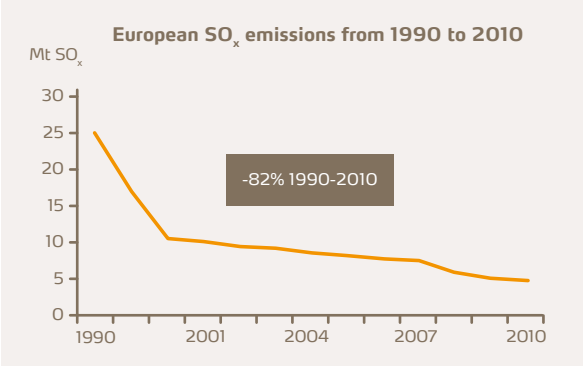


Figure 2: Sulfur emissions – and depositions – have dropped significantly as a consequence of environmental regulation [1].

SYMPTOMS APPEAR LATE

Sulfur deficiency is sometimes hard to distinguish from nitrogen deficiency, to which it may be linked. Symptoms include a yellowing of the younger leafs, as a result of low chlorophyll production. Growth is generally diminished. In cereals, the tiller number is reduced. In rapeseed, flowering turns to white and leafs are distorted. In most cases, symptoms appear too late for efficient compensation. Hidden deficiency is by far more frequent than acute deficiency.

Figure 3: Characteristic aspect of a field with advanced localized sulfur deficiency.

Figure 4: Rapeseed with advanced sulfur deficiency (left). Growth is diminished, flowering is sparse and white.

Figure 5: Grassland with advanced localized sulfur deficiency (in the back).

Sulfur in the soil

The sulfur cycle in the soil shows some similarities with the nitrogen cycle. Sulfur resides in different, interconnected pools. Only a minor part of it is immediately available for plant uptake. The rest needs to undergo transformation processes first.

What are the specificities of sulfur?

CROPS PREFER SULFATE

Plant roots can take up sulfur only as sulfate ions (SO_4^{2-}). Plant leaves can also take up sulfur from the air as sulfur dioxide (SO_2), but this contribution is now minor. All elementary soil sulfur must first be mineralized before it becomes available to plants.

SOURCES OF SULFUR

All sulfur in the soil, whether it was applied as elementary sulfur, manure or sulfate, ends up as sulfate before plants take it up. If sulfate is applied directly, losses are avoided.

Sulfur from mineral fertilizers

Mineral fertilizer contains sulfur as sulfate. Unlike organic sulfur compounds from manure, sulfate from fertilizer is immediately available as a nutrient and easily absorbed by plants. Sulfate is highly mobile in the soil and reaches the plant roots quickly. The application of sulfur during an early stage and during intensive plant growth makes it suitable for combination with other fertilizers, especially nitrogen. Spreading is therefore the common practice. In case of acute sulfur deficiency, foliar application can provide a fast relief. Sulfur applied as elementary sulfur needs to be oxidized to sulfate by soil microbes, which takes time. Elementary sulfur also has a strong acidifying effect.

Depositions from the air

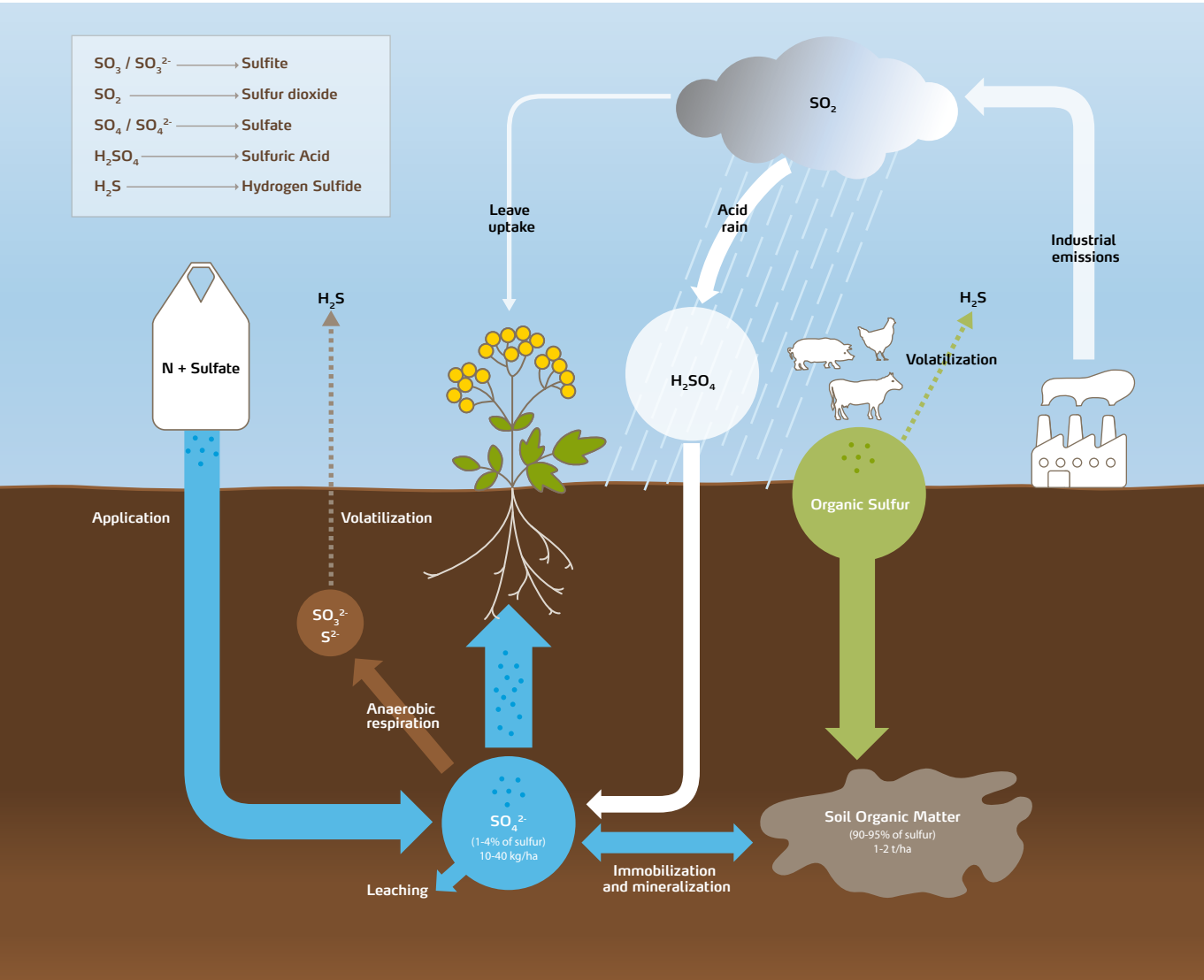
Sulfur is present in the atmosphere mainly as sulfur dioxide (SO_2) from natural events (volcanic eruptions) or manmade activities (burning of fossil fuels). Sulfur can enter the leaves of plants from the air as sulfur dioxide gas. Most of the atmospheric sulfur, however, enters the soil as acid rain. Depositions have dropped significantly and hardly exceed 10 kg/ha today.

Manure

Manure contains sulfur mainly as organic matter and therefore needs to be mineralized before it can be taken up.

Sulfur leaching

Sulfur behaves similar to nitrogen in the soil. Sulfate ions, as nitrate ions, are dissolved and prone to leaching. Fertilization shall therefore be matched to plant growth in order to ensure rapid uptake. Application in the early phase of plant growth is most efficient. Stock fertilization in autumn is generally not recommended.



How much sulfur **is enough?**

When it comes to sulfur, crops are not equal. For some crops, soil supply can be sufficient while sever losses in quantity and yield are to be expected for others without appropriate sulfur fertilization. Sulfur fertilization, other than nitrogen fertilization, is often guesswork.

How much is enough?

SULFUR NEEDS

Some crops need more sulfur than others. The following table summarizes crop needs as well as the amount of sulfur exported from the field and retained by crop residues. The higher the sulfur demand, the higher the sensitivity to deficiency. Rapeseed has a very high uptake, but most of the sulfur remains in plant residues.

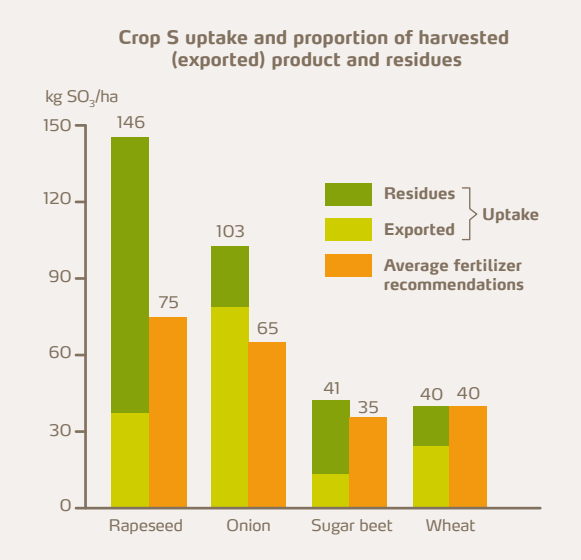


Figure 6: Crop S uptake and content in harvested product and residues compared to fertilizer recommendations [2][3].

UPTAKE DYNAMICS

Cumulated uptake is only one aspect of sulfur needs. Uptake dynamics are the other important aspect. Sulfur is required at all stages of the growth process. Crops with a short vegetation period need high amounts of sulfur in a short time and these needs are generally not covered by soil supply. Plants with a longer vegetation cycle have more time to recover sulfur from the soil and are therefore less dependent on external supply. Rapeseed is specifically demanding with regard to sulfur, due to its short vegetation cycle and high uptake. Sulfur deficiency can therefore cause yield losses of up to 1 or 2 t/ha.

SOIL SAMPLING

As with nitrogen, soil sampling enables quantification of actually available sulfate in the soil. Results, however, change rapidly due to lower plant uptake, continued mineralization, capillary rise and leaching. Soil sampling is therefore rarely used except for rich soils and demanding crops such as rapeseed.

PLANT ANALYSIS

The amount of sulfur in dry matter is a reliable indicator for sulfur deficiency. Sulfur concentrations shall exceed 0,3 % of dry matter for most crops and 0,45 % for rapeseed. Plant analysis in addition enables measuring N:S ratios. These are meaningful indicators for most crops. The Yara Megalab service offers fast and reliable analysis to precisely tailor fertilization rates.

Crop	Typical N:S ratios
Rapeseed, mustard, cabbage, bulbs	5:1
Wheat, corn, sugar beets, potatoes	10:1
Leguminous	5 – 8:1
Grass	8 – 12:1

Table 1: N:S ratios are meaningful indicators for plant status and nutrient needs [4].

ESTIMATION CHARTS

Sulfur requirements can also be estimated by means of observation. Charts and software tools have been developed to help farmers evaluate various parameters such as soil structure, weather conditions, crop systems and previous fertilization. These estimations have proven good reliability under real farming conditions.

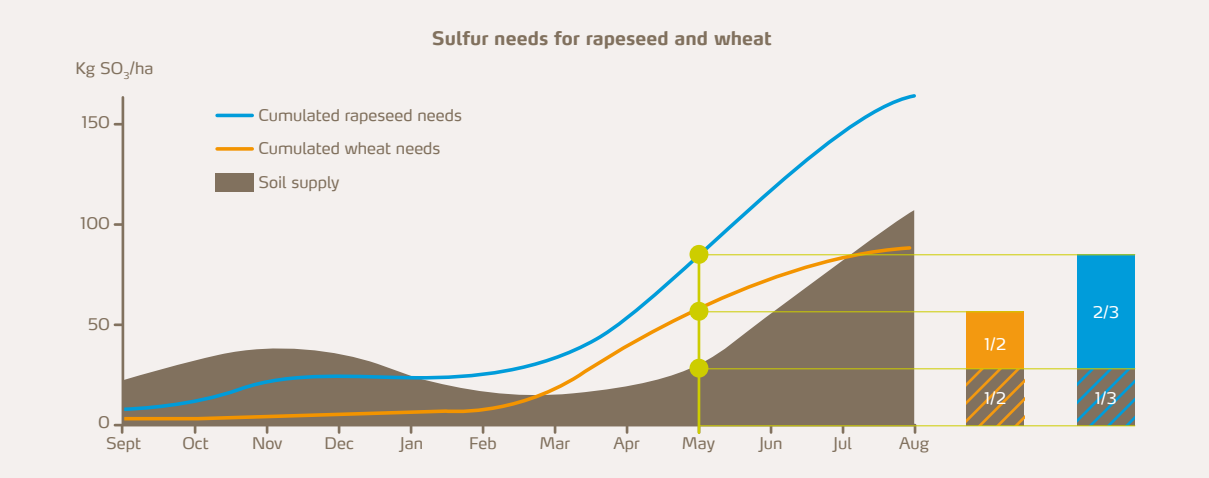


Figure 7: During the growing season, sulfur needs for rapeseed and wheat exceed by far the S supplied by soil. In May, typically half of sulfur needs are missing for wheat and even two thirds for rapeseed [5].

Sulfur fertilization – what is it worth?

Agronomic and economic considerations are not always converging. Is the additional cost of sulfur fertilization well invested? The answer of course depends on crops and soil characteristics. Moreover, farming strategies are to be taken into account.

High quality - high yield strategies require a careful adjustment to sulfur needs.

WHEAT: INCREASING YIELD AND PROTEIN

Sulfur is key when it comes to fertilization strategies that target highest quality. Figure 8 shows the result of field trials in Germany for different scenarios.

Yield and protein content were compared for mean and high nitrogen intensity strategies. The results show the potential of sulfur in high value cropping strategies.

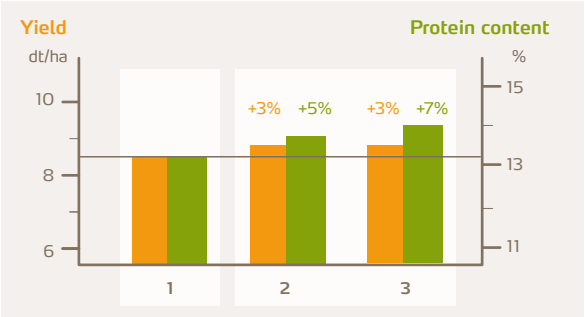


Figure 8: Comparison of yield and protein content for different fertilization strategies: 1) mean nitrogen intensity, no sulfur; 2) high nitrogen intensity (+30 kg N), one application of sulfur at the first dressing (+15 kg S); 3) high nitrogen intensity (+30 kg N), sulfur application at the first (+15 kg S) and third dressing (+15 kg S). Optimum nutrition enables 7% increase in protein content [6].

GRASSLAND: INCREASING ENERGY

Yield, energy content, raw protein content and raw fiber content of grass silage increase with sulfur application. Split application has demonstrated superior yield performance over no or one single application (figure 9).

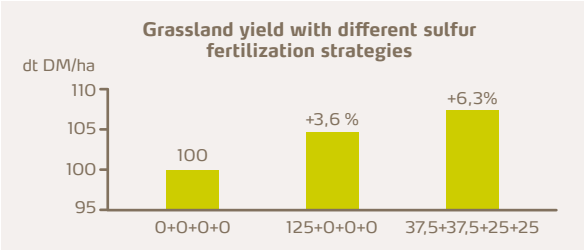


Figure 9: Mean yield from 3 trials in Germany. Yield increases by 3,6% with one application of 125 kg sulfate ($CaSO_4$) at the first cut. If the same amount of sulfur is split between 4 applications, yield increases again, reaching 6,3% above the reference level [7].

RAPESSED: SULFUR DEMANDING

Rapeseed is a demanding sulfur crop, mobilizing up to 180 kg SO_3/ha. However, a significant proportion of oilseed rape crops receive no specific sulfur fertilization. Mean yield losses in case of sulfur deficiency are around 3 to 4 q/ha but can reach 15 to 20 q/ha in case of severe deficiency.

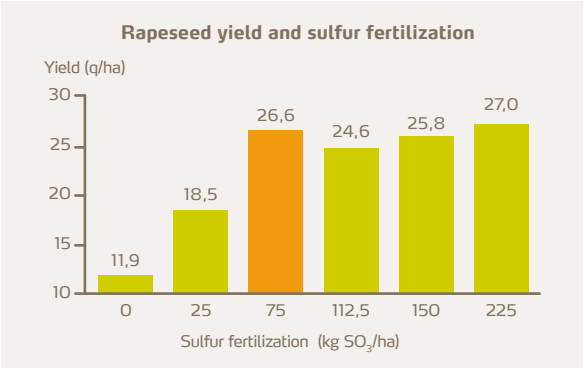


Figure 10: The optimal sulfur fertilization rate is 75 kg/SO_3 [8]

ENHANCING YIELD AND RETURNS

A great number of field trials have proven the benefits of tailored N/S fertilization on various crops.

Crop	Average price* (€/t)	Additionnal yield (dt/ha)		Additionnal income (€/ha)
		Mean	Max	Mean
Rapeseed	430	4,2	17,6	181
Wheat	220	1,4	5,6	31
Sugarbeet**	373	3,1	5,6	116
Potatoes	120	7,1	11,6	85
Grassland	130	7,7	11,6	100

*Source: Eurex 2012 **Based on corrected sugar yield

Table 2: For most crops, yield and additional gross income increases significantly when using N/S fertilizer [9].

YaraBela® Sulfan® – **perfect synergy**

YaraBela Sulfan is a high performance fertilizer containing ammonium nitrate and sulfur for optimum synergy. As all fertilizers of the YaraBela range, it offers superior mechanical and chemical quality for unrivalled performance and returns.

YaraBela Sulfan - added value from Yara.

ADAPTED TO ALL CROPS

YaraBela Sulfan contains nitrogen as ammonium nitrate and sulfur as calcium sulphate, ensuring optimum N and S efficiency. Unlike blended fertilizers, YaraBela Sulfan provides a balanced, homogeneous N/S ratio within each individual granule. YaraBela Sulfan is a pure nutrient optimally suited for precision farming and split application:

- Compound fertilizer for simultaneous, time-saving spreading of nitrogen and sulfur.
- Ammonium nitrate for optimum nitrogen efficiency.
- Calcium sulfate for optimum sulfur supply and low liming requirements without loss of N efficiency.
- High density granules with low granulometric spread for utmost spreading precision.
- High solubility and optimum absorption dynamics.

YaraBela Sulfan is a granulated fertilizer made for high performance spreading. It is manufactured in Europe according to the strict environmental and quality requirements of Yara. YaraBela Sulfan is the natural choice for farmers who care for yield and quality.

	N	S	Mg
YaraBela Sulfan	24	6	
YaraBela Optimag	24	17	4

Table 3: Available formulations.

For further information about nitrate fertilizers, get the complete nitrate fertilizer brochure from www.yara.com

For multimedia contents on farming, visit our YouTube Channel: www.youtube.com/yarainternationalasa

ABOUT YARA

Yara International ASA is an international company headquartered in Oslo, Norway. As the world's largest supplier of mineral fertilizers for more than a century, we help to provide food and renewable energy for a growing world population.

Yara provides quality products, knowledge and advice to farmers. Please do not hesitate to contact one of our local agronomists for further information.

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