TESSENDERLO Kerley

Thio-Sul®

EST. 1919

APPLICATION GUIDE

HIGH PERFORMANCE LIQUID NITROGEN WITH THIOSULFATE SULFUR

TESSENDERLO Kerley

Tessenderlo Kerley International's liquid fertilizers deliver liquid precision to the crop: more precise application and more efficient nutrient uptake.

- Active Thiosulfate is a versatile technology with double action: it brings a key nutrient and acts as an activator enhancing the uptake of other nutrients, thus optimizing overall fertilizer efficiency.
- We bring a new generation of liquid fertilizers – innovative products for more precise and environmentally responsible yield & crop quality improvement.

The importance of nitrogen and sulfur

Nitrogen and sulfur are important components of proteins. Sulfur deficiency may affect the plant's ability to utilize nitrogen for protein synthesis.

- Nitrogen is the nutrient that promotes the growth and vigor of the plant.
- It is also one of the fundamental elements of plant nutrition, since it is included in the composition of chlorophyll.
- Sulfur also plays a role in the formation of chlorophyll that permits photosynthesis.
- It is also important for the activation of enzymes, which aid in biochemical reactions in the plant, and in the formation of proteins, sulfolipids and glucosinolates.

Thio-Sul® is a clear liquid ammonium thiosulfate solution that helps increase yields by satisfying a crop's essential need for nitrogen and sulfur.

- Mixed with your nitrogen solutions, an effective and economical way to reduce nitrogen loss due to ammonia volatization and to slow down nitrification.
- 100 % compatible with N solutions including UAN and liquid manures.
- Liquid fertilizer without chloride.
- Delivers sulfur in 100% liquid form.

INTRODUCTION

Thio-Sul® is the original nitrogen-sulfur plant nutrient solution instrumental in unlocking the full potential of your fertilization program. Thio-Sul is a clear liquid containing 12% N and 26% S and is the most popular S-containing product used in the liquid fertilizer industry. Each litre of Thio-Sul contains 160 grams of nitrogen (N) and 346 grams of sulfur (S). Thio-Sul can be applied by drip, sprinkler or flood irrigation, as well as by broadcasting, banding, injection in the soil, and using liquid fertilizer nozzles. It may be blended with other fertilizers or applied as a foliar treatment on selected crops.

Thio-Sul aids in increasing crop yields and enhancing fertilizer cost-effectiveness by improving the nitrogen-sulfur balance and helps in maintaining necessary sulfur levels in sulfur deficient soils and crops.

Thio-Sul can be applied to a wide variety of field and cash crops as well as turf.

BENEFITS OF THIO-SUL

- Is a highly efficient liquid source of N and S, essential for all crops.
- Reduces soil alkalinity.
- Excellent urease & nitrification inhibitor.
- Improves aeration of the soil.
- Helps facilitate the decomposition of crop residues.

Liquid fertilizer benefits

- Easy to handle and safe to use.
- Cost effective with uniform field application.
- Fully compatible with irrigation systems and sprayers.
- Reduced environmental impact compared to conventional fertilizers.
- Does not plug drip lines or spray nozzles.
- Uniform field application.
- Liquid precision - ideal for localized application.

Active thiosulfate benefits

- Enhances crop protein and chlorophyll content.
- Assists the synthesis and functioning of enzymes in the plant.
- Optimizes fertilizer efficiency by stabilizing nitrogen.
- Improves availability of nutrients in the soil, particularly phosphorus and micronutrients and their uptake by the crop.
- Energy efficient assimilation in the plant.
- Beneficial soil microorganism interaction.
- A controlled and localized pH adjustment effect in the soil.
- A high content of sulfur, half in reduced form and half in oxidized form, provides prolonged sulfur nutrition.

SUMMARY OF APPLICATIONS

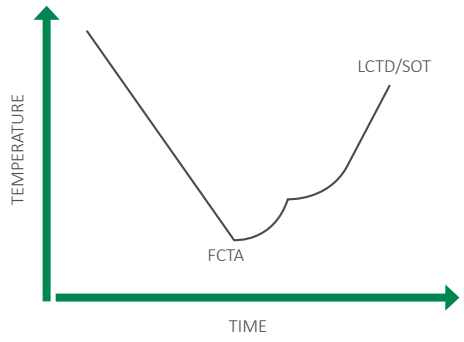
- Compatible with open field cultivation as well as cultivation under cover in tunnels and in greenhouses.
- Versatile - can be applied both straight and in blends via soil injection and as a top dressing using liquid fertilizer nozzles, as well as by broadcasting and banding and also via drip irrigation, sprinklers and pivots.
- Suitable for use in all crops but is particularly recommended for optimizing the nitrogen-sulfur balance when fertilizing field crops.
- Foliar application of Thio-Sul using a boom sprayer equipped with crop protection nozzles is **not recommended**.
- For best management practices and utilization of nitrogen and sulfur, apply Thio-Sul with enough UAN solution or aqueous ammonia to give the optimal N:S ratio for the crop. (Typically between 3:1 and 9:1 in the blend). Plant tissue analysis is recommended to determine a crop's sulfur requirement.
- Most crops need between 20-50 kg/ha sulfur (58-145 l/ha Thio-Sul) per crop depending upon local growing conditions, soil type, fertilizer placement, crop and yield potential.
- For best results, follow soil and plant tissue analysis guidelines on sulfur nutrition for crops in your area.

COMPATIBILITY

Thio-Sul is compatible with N solutions and complete (N-P-K) liquid blends that are neutral to slightly acidic. In addition to its wide adaptability for use in clear liquid blends, it is also well suited for use in suspensions. **Thio-Sul cannot be used with acidic (pH < 6.0) materials.** Thio-Sul is often applied in combination with UAN solutions and aqueous ammonia to supply the sulfur needs of crops and improve nitrogen use efficiency.

SPECIFICATIONS

- N (w/w) as ammoniacal nitrogen	12%
- S (w/w)	26%



TYPICAL PROPERTIES

- Appearance/color	Clear, colorless to light yellow
- pH range	6.5 - 8.5
- Density range (at 25°C)	1.32 kg/l - 1.35 kg/l
- Salt out temperature (SOT)	+ 4°C
- Crystallization temperature	Approx 0°C
- Recommended minimum storage temperature	8°C
- SO_3 (w/w)	64.9%
- N (w/v) as ammoniacal nitrogen	16%
- S (w/v)	34.6%
- SO_3 (w/v)	86.3%
- N (g/l)* as ammoniacal nitrogen	160
- S (g/l)*	346
- SO_3 (g/l)*	863
- Chemical formula	$(NH_4)_2S_2O_3$

** Based on a typical density of 1.33 kg/l at 25 °C*

CRYSTALLIZATION TEMPERATURE AND SALT OUT TEMPERATURE (SOT)

As solutions of certain liquid fertilizers cool down, a point may be reached where material starts to precipitate or 'salt out' from the solution. This temperature point is often referred to as the 'First Crystal to Appear' (FCTA) or **Crystallization Temperature** (see graph). Once crystals have formed in a solution it is normally possible to re-dissolve them by warming up the solution again. During this warming process, the point at which this last crystal re-dissolves is usually referred to as the 'Last Crystal to Dissolve' (LCTD) or 'Thaw Point'. When cooling, the FCTA point observed for a particular liquid fertilizer will depend on a number of variables. These can include the source and exact composition of the product (manufacturer), the speed at which temperature drops, and how long the temperature remains below the recommended storage temperature. Because of this variability in the FCTA point, the **Salt Out Temperature (SOT)** in most cases for a liquid fertilizer is defined as the temperature (LCTD) at which the last crystal dissolves (is no longer visible in solution) during rewarming.

Tessenderlo Kerley International uses an industry accepted, documented, and standardized method based on FCTA and LCTD definitions to determine SOT of its liquid fertilizers.

The **Minimum Recommended Storage Temperature** for our liquid fertilizers is generally several degrees higher than the measured SOT and it is a temperature above which, based on practical experience, there should be virtually no risk of salt out. The Salt Out Temperature of Thio-Sul is several degrees lower than the recommended minimum storage temperature and the FCTA point is often even lower than the SOT.

STRAIGHT APPLICATION OF THIO-SUL

SOIL APPLICATION

CROP	APPLICATION METHOD	DOSE L/HA/ APPLICATION (MAX)	NUMBER OF APPLICATIONS 10-14 DAYS BETWEEN APPLICATIONS	TIMING	OBSERVATIONS/ PRECAUTIONS
Wheat, barley, oats, rye	Boom spray on the soil	150	1	Before sowing or after harvesting previous crop	
	Sprayer with special hanger tubes/soil injection	90	3	From crop emergence to BBCH 51	Avoid contact with the leaves
	Sprayer with liquid fertilizer (stream jet) nozzle	90	3	From crop emergence to BBCH 33	If necessary the solution can be diluted with water
Rapeseed	Boom spray on the soil	100	1	Before sowing or after harvesting	
	Sprayer with special hanger tubes	110	2	BBCH 30-32 and before BBCH 50	Avoid contact with the leaves
	Sprayer with liquid fertilizer (stream jet) nozzle	110	2		If necessary the solution can be diluted with water
Corn	Boom spray on the soil	150	1	Before sowing or after harvesting	
	Soil injected > 30 cm side	100	2	BBCH 14 to BBCH 19	Avoid contact with the leaves and seeds
	Soil injected < 30 cm side	50	2		
	Sidedressing - special equipment	70	2		
	Starter special kit (5x5)	70	1	At sowing	
Soybean	Boom spray on the soil	110	1	Before sowing or after harvesting	
	Sprayer with special hanger tubes	100	3	BBCH 14 to 79	Avoid contact with the leaves and seeds
	Soil injected > 30 cm side	100	2		
	Soil injected < 30 cm side	50	2		
	Starter special kit (5x5)	70	1	At sowing	
Sunflower	Boom spray on the soil	110	1	Before sowing or after harvesting	
	Soil injected > 30 cm side	100	2	BBCH 14-20 and before BBCH 50	Avoid contact with the leaves and seeds
	Soil injected < 30 cm side	50	2		
	Sidedressing - special equipment	100	2		
	Starter special kit	70	1	At the sowing time 5 x 5 cm	
Sugarbeet	Boom spray on the soil	100	1	Before sowing or after harvesting	
	Sprayer with special hanger tubes	100	2	Before "row closing"	Avoid contact with the leaves
Potatoes	Starter special kit	15	1	At the sowing time	Avoid contact with the tubers
	Boom spray on the soil	100	1	Before sowing or after harvesting	
	Sprayer with liquid fertilizer (stream jet) nozzle	100	1	Before crop emergence	
Buckwheat, linseed	Boom spray on the soil	100	1	Before sowing or after harvesting	
	Sprayer with special hanger tubes	100	2	Before flowering	Avoid contact with the leaves
Alfalfa	Boom spray on the surface	90	1	Immediately after a cutting or during dormancy	

CROP	APPLICATION METHOD	DOSE L/HA/ APPLICATION (MAX)	NUMBER OF APPLICATIONS 10-14 DAYS BETWEEN APPLICATIONS	TIMING	OBSERVATIONS/ PRECAUTIONS
Other root crops and vegetable crops	Starter fertilizer (band application 5cm to the side and 5cm below the seed row)	60	1	At sowing	Avoid contact with the seeds For pre-plant soil injection application Do not apply Thio-Sul where it will be in direct seed contact
	Side dressing - special equipment	120	1	During vegetative growth	If injection applications are made close to the row (less than 30 cm) reduce application rate by approximateky half (up to 60 liters per hectare) Avoid root pruning
Trees and vines	Soil injection and surface banding (not recommended for shallow roots)	90	1	Early in the growing season	Avoid pruning roots during injection application
	Boom spray on the soil	110	1	Before flowering	Spray by itself or mixed with water and/or other liquid fertilizers For young trees and vines up to 75 liters per hectare Prevent spray and drift from contacting crop foliage and tree bark

Precautions

- If injection applications are made close to the row (less than 30 cm), reduce application rate. Avoid root pruning.
- Thio-Sul should not be mixed with acids or other acidic material below a pH of 6.0.
- Do not top-dress with Thio-Sul when temperatures are above 25°C and relative humidity is below 30%.
- Rates will vary depending on crop requirement and soil analysis.
- Do not apply Thio-Sul when crops are experiencing heat or moisture stress.

FERTIGATION

Fertigation is the practice of injecting soluble fertilizers through irrigation systems using water as a nutrient delivery system to the crop. Before injecting Thio-Sul into an irrigation system, make sure that the irrigation system is in good condition and provides uniform distribution to the field. Application of nutrients like Thio-Sul should be made in the middle third or second half of an irrigation set.

- The injection of Thio-Sul should be done slowly, and should last at least as long as it takes irrigation water to travel from the point of injection to the last emitter or sprinkler in the field.
- The injection of Thio-Sul should be done with a fertilizer injection pump and should be done over a 1 to 4 hour time period.
- Rapid injection of Thio-Sul may lead to uneven distribution of fertilizer and may cause crop damage.

For additional information about injection of nutrients into an irrigation system, consult with your local agronomist and review the International Fertilizer Industry Association (IFA) publication ”Fertigation: A tool for efficient fertilizer and water management” (U. Kafkafi and J. Tarchitzky).

All rates listed are for crops growing on medium to fine textured soils (suggested rates are for trees and vines at least 4 years old or older). Avoid application to new plantings until crop is well established. For sandy soils, suggested rates should be reduced by 50%. Do not apply Thio-Sul when crops are experiencing heat or moisture stress.

Flood and in furrow application

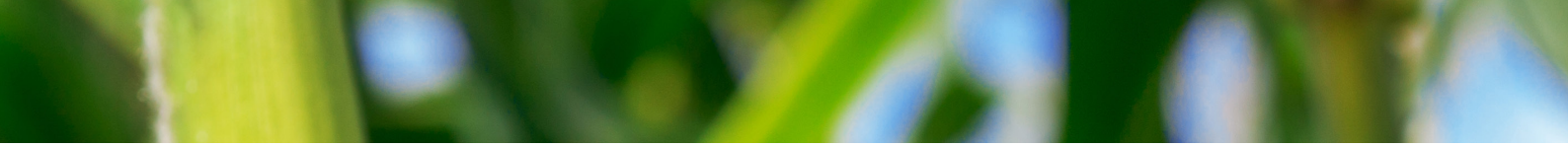
Thio-Sul may be applied with irrigation water. For best management practices, applications should be made when the crop may best utilize the nitrogen and sulfur. Apply 45 to 90 liters per hectare of Thio-Sul on lighter soils and 75 to 150 liters per hectare on heavier soils. Apply throughout majority of the crop's irrigation period.

CROP	DOSE L/HA/ APPLICATION* (MAX)	NUMBER OF APPLICATIONS 10-14 DAYS BETWEEN APPLICATIONS	TIMING
Wheat, barley, oats, rye	30-50	3	BBCH 20 to 51
Rapeseed	30-50	3	BBCH 30-32 and before BBCH 50
Corn	30-50	2	BBCH 14-16 to BBCH 50
Soybean	30-50	2	BBCH 14 to 79
Sunflower	30-50	2	BBCH 14-20 and before BBCH 50
Sugarbeet	30-50	3	Before "row closing"
Potatoes	30-50	2	As per irrigation/fertilization plan, until flowering
Buckwheat, linseed	30-50	2	Before flowering
Alfalfa	45-75	2	Apply on established crop
Row and vegetabe Crops	45-75	2	Before flowering
Trees and vines	45-75	2	Before flowering

**Depending on soil type*

Sprinkler/Centre Pivot irrigation

CROP	DOSE/HA/ APPLICATION (MAX)	NUMBER OF APPLICATIONS 10-14 DAYS BETWEEN APPLICATIONS	TIMING
Wheat, barley, oats, rye	50	3	BBCH 20 to 51
Rapeseed	50	3	BBCH 30-32 and before BBCH 50
Corn	50	2	BBCH 14-16 to BBCH 50
Soybean	50	2	BBCH 14 to 79
Sunflower	50	2	BBCH 14-20 and before BBCH 50
Sugarbeet	50	3	Before "row closing"
Potatoes	50	2	As per irrigation/fertilization plan, until flowering
Buckwheat, linseed	50	2	Before flowering
Alfalfa	90	1	After cutting
Row and vegetabe Crops	45	As needed	Apply at planting or wait until the crop is at the 3rd or 4th leaf stage
Trees (under)	75	As needed	Beginning at full leaf stage
Trees (over)	35	As needed	Beginning at full leaf stage
Vines (over)	35	As needed	Up to flowering



Drip irrigation

Thio-Sul has been developed for use in fertigation and the product has all the necessary characteristics to be ideal for this application.

Calculations for specific solution concentrations are given below. A typical scenario is that a nutrient solution of 80 mg N per liter requires a stock solution of 10.03 l Thio-Sul per 100 liters of water, injected at a rate of 0.5%.

For scenarios not described in the table, the following formulae can be used to calculate the relevant solution concentrations:

- Nutrient solution (N ppm or N mg/l) = 15.96 x concentration of stock solution (l Thio-Sul per 100 l water) x % injection rate.
- Stock solution (l Thio-Sul per 100 l water) = 0.0627 x concentration of nutrient solution (N ppm or N mg/l) / % injection rate.

NUTRIENT SOLUTION (N ppm or N mg/L)	STOCK SOLUTION (L of Thio-Sul per 100 liters of water) at an injection rate of		
	1%	**0.8%**	**0.5%**
20	1.25	1.57	2.51
40	2.51	3.14	5.02
60	3.76	4.70	7.52
80	5.02	6.27	**10.03**
100	6.27	7.84	12.54
120	7.52	9.41	15.05
140	8.78	10.97	17.56
160	10.03	12.54	20.06
180	11.29	14.11	22.57
200	12.54	15.68	25.08

CROP	DOSE L/HA/ APPLICATION (MAX)	NO. OF APPLICATIONS	TIMING
Sugarbeet	50	3 at 10-14 day intervals	Apply with full irrigtion as per fertigation plan until “row closure”
Potatoes	50	2 at 10 to 14 day intervals	Apply with full irrigtion as per fertigation plan until flowering
Row and vegetabe crops (drip tape and subsurface drip)	20	As needed every 7 to 10 day	Apply with full irrigtion as per fertigation plan until flowering
Trees and vines (subsurface drip)	75	As needed every 14 to 21 days	Apply with full irrigtion as per fertigation plan until flowering
Trees and vines (drippers and mini spinklers)	75	As needed every 14 to 21 days	Apply with full irrigtion as per fertigation plan until flowering For young trees and vines apply up to 35 liters of Thio-Sul per hectare

Directions for use of Thio-Sul in drip irrigation

To get the best results from Thio-Sul in fertigation programs using injection of stock solutions, the guidelines below should be followed:

- Add ½ of water to tank, begin stirring.
- With highly alkaline water (pH > 8), it is recommended to first neutralize the stock solution to pH 7 before addition of Thio-Sul.
- Add recommended amount of Thio-Sul followed by the other compatible liquid N and P sources.
- Add compatible micronutrients, followed by flowable materials, then by emulsifiables and finally any soluble powders and/or water soluble fertilizers. (All should be pre dispersed in water before adding to the tank solution.)
- Complete filling of tank to desired volume and continue circulating prior to and during injection.
- Flush equipment after usage.
- It is highly recommended to conduct a small scale trial to check the compatibility of the mixture before large scale operation and injection into the irrigation system.
- Always refer to instructions for use and precautions given for the product.

Precautions

- Before injecting Thio-Sul into an irrigation system, make sure that the irrigation system is in good condition and provides uniform distribution to the field.
- Application of nutrients like Thio-Sul should be made in the middle third or second half of an irrigation set. Several hours of irrigation should take place before and after the injection of Thio-Sul.
- Do not apply Thio-Sul while chlorinating irrigation system. Thiosulfates will neutralize chlorine.
- Fertigation application of Thio-Sul and other liquid fertilizers to an established crop may cause injury to a crop if:
  - injection period is less than 60 minutes, which may cause an uneven distribution of Thio-Sul to the crop
  - Thio-Sul rates are higher than suggested
  - ample irrigation water is not applied immediately before and after the injection of Thio-Sul
- After injection, allow enough irrigation time (at least 60 minutes) to rinse the plants of any residual fertilizer.
- The injection should be done slowly, and should last at least as long as it takes irrigation water to travel from the point of injection to the last emitter or sprinkler in the field.
- Rapid injection may lead to uneven distribution and may cause crop damage.
- After injection, allow enough irrigation time (at least 60 minutes) to rinse the plants of any residual fertilizer.

APPLICATION OF THIO-SUL IN BLENDS

BLENDING OF THIO-SUL

- Thio-Sul is compatible with most fertilizer solutions.
- In absence of specific recommendations and data, do a jar test before mixing large quantities.
- Thio-Sul can be blended with UAN or urea solution in any ratio to supply nitrogen and sulfur.
- The addition of water to the mixture may be helpful to maintain blend stability.
- When blending with micronutrients trial blends should be made before mixing large amounts.
- When mixing other liquid fertilizers with Thio-Sul, the blend sequence should be as follows: water, pesticide, Thio-Sul and/or other fertilizer.
- Blends of Thio-Sul should not be acidified below a pH of 6.0.

THIO-SUL AS A NITROGEN STABILIZER

University research has shown that Thio-Sul acts as a nitrification inhibitor when blended with UAN solution resulting in more nitrogen being available to the crop. Thio-Sul, when added to UAN solution at a minimum 10% volume-to-volume ratio, delays nitrification, resulting in a decrease of potential losses from nitrate nitrogen leaching. Thio-Sul, when added to UAN solution or aqua ammonia, allows the plant to better utilize the applied nitrogen. Not only does Thio-Sul stabilize the nitrogen for plant use, but it is an excellent source of sulfur as well.

THIO-SUL IN COMBINATION WITH UREA AMMONIUM NITRATE (UAN)

Urea ammonium nitrate (UAN) is an effective and balanced source of nitrogen, providing excellent value for money. It can be applied accurately for fertilization via leaves and soil and, when spraying, can be applied uniformly over wide areas. It is easily combined with Thio-Sul and the resulting mixtures (known as 'NTS Thio-Sul inside'™) are simple to use. For optimal results Tessenderlo Kerley International recommends that the ratio of Thio-Sul within the UAN solution should be 10% to 30% w/w.

TYPICAL PROPERTIES	UAN 28	UAN 30	UAN 32
Total N (w/w)	28%	30%	32%
Total N (g/L)*	358	390	422
Nitrogen content (w/w) as a percentage of the total N present in the product			
Urea (w/w)	28 - 32%	30 - 34%	33 - 37%
N (w/w) as ureic nitrogen	13 - 15%	14 - 16%	15 - 17%
Ammonium nitrate (w/w)	37 - 43%	40 - 46%	42 - 48%
N (w/w) as ammoniacal nitrogen	6.5 - 7.5%	7 - 8%	7.5 - 8.5%
N (w/w) as nitrate nitrogen	6.5 - 7.5%	7 - 8%	7.5 - 8.5%
N (w/w) as free ammonia	0.03 - 0.05%	0.03 - 0.05%	0.03 - 0.05%
Urea (g/L)	358 - 410	390 - 442	436 - 481
N (g/L)* as ureic nitrogen	166 - 192	182 - 208	198 - 224
Ammonium nitrate (g/L)*	474 - 550	520 - 598	554 - 634
N (g/L) as ammoniacal nitrogen	83 - 96	91 - 104	99 - 112
N (g/L) as nitrate nitrogen	83 - 96	91 - 104	99 - 112
N (g/L) as free ammonia	0.4 - 0.6	0.4 - 0.6	0.4 - 0.6
	UAN 28	UAN 30	UAN 32
Appearance / Color	Clear, with a slight tint		
pH range	6.5 - 7.5		
Density range at 16-20°C (kg/L)	1.27 - 1.29	1.29 - 1.31	1.31 - 1.33
Chemical Formula	CH_4N_2O/NH_4NO_3 (urea/ammonium nitrate)		

** Based on a typical density of 1.28 kg/l (UAN 28); 1.30 kg/l (UAN 30) and 1.32 kg/l (UAN 32) all at 16°C*

High efficiency NTS is a liquid fertilizer blend composed of UAN (urea ammonium nitrate solution) mixed with Thio-Sul (ammonium thiosulfate). It offers the following benefits:

- An ammonium based fertilizer with a slow release effect giving more regular plant growth.
- Helps reduce ammonia volatization.
- Slows down the conversion of ammonium to nitrate: reduces of the risk of leaching, and thus, more nitrogen is available for the plants.
- Less nitrogen losses due to the lower mobility of the ammonium in the soil.
- Stimulates root growth.
- Provides continuous N and S replenishment via the thiosulfate component.
- Helps to increase yields along with protein quantity and quality.

One of the advantages of NTS blends is that different proportions of nutrients can be mixed, e.g. 27% N + 3% S (6.5% nitrate-N, 7.5% ammonium-N, 13% urea-N) or 24% N + 6% S (5% nitrate-N, 8% ammonium-N, 11% urea-N). NTS fertilization is potentially of interest to those looking to:

- Minimize nitrogen losses.
- Store fertilizers more cost-effectively.
- Simplify fertilizer logistics.
- Manage your fertilizer inventory in an efficient and economical way.

Typical properties of NTS Mixtures

THIO-SUL (W/W) IN THE UAN SOLUTION†	BASED ON UAN 28 (W/W)		BASED ON UAN 30 (W/W)		BASED ON UAN 32 (W/W)	
	Composition of resulting NTS blend		**Composition of resulting NTS blend**		**Composition of resulting NTS blend**	
	% N (w/w)	% SO_3 (w/w) % S (w/w)	% N (w/w)	% SO_3 (w/w) % S (w/w)	% N (w/w)	% SO_3 (w/w) % S (w/w)
10%	26.4% (6.3% nitrate-N) (7.5% ammoniacal-N) (12.6 % ureic-N)	6.5% 2.6%	28.2% (6.8% nitrate-N) (8.0% ammoniacal-N) (13.5% ureic-N)	6.5% 2.6%	30% (7.2% nitrate-N) (8.4% ammoniacal-N) (14.4% ureic-N)	6.5% 2.6%
15%	25.6% (6.0% nitrate-N) (7.8% ammoniacal-N) (11.9 % ureic-N)	9.8% 3.9%	27.3% (6.4% nitrate-N) (8.2% ammoniacal-N) (12.8% ureic-N)	9.8% 3.9%	29% (6.8% nitrate-N) (8.6% ammoniacal-N) (13.6% ureic-N)	9.8% 3.9%
20%	24.8% (5.6% nitrate-N) (8.0% ammoniacal-N) (11.2% ureic-N)	13.0% 5.2%	26.4% (6.0% nitrate-N) (8.4% ammoniacal-N) (12% ureic-N)	13.0% 5.2%	28% (6.4% nitrate-N) (8.8% ammoniacal-N) (12.8% ureic-N)	13.0% 5.2%
25%	24% (5.3% nitrate-N) (8.3% ammoniacal-N) (10.5% ureic-N)	16.3% 6.5%	25.5% (5.6% nitrate-N) (8.6% ammoniacal-N) (11.3% ureic-N)	16.3% 6.5%	27% (6.0% nitrate-N) (9.0% ammoniacal-N) (12.0% ureic-N)	16.3% 6.5%
30%	23.2% (4.9% nitrate-N) (8.5% ammoniacal-N) (9.8% ureic-N)	19.5% 7.8%	24.6% (5.2% nitrate-N) (8.8% ammoniacal-N) (10.5% ureic-N)	19.5% 7.8%	26% (5.6% nitrate-N) (9.2% ammoniacal-N) (11.2% ureic-N)	19.5% 7.8%

† The difference between the UAN grades is the slight increase of water content going from UAN 32 to UAN 28, which as a result reduces the SOT.
Figures in the table are on a weight per weight (w/w) basis - for a weight per volume basis (w/v) conversion will be required

Application recommendations for NTS mixtures

The following fertilizer recommendations are based on the results of several years of experience gathered from research and practice. The amount of fertilizer required is based on the expected yield and results of soil and crop analysis (fertilizer demand determination). NTS mixtures can cover the exact nitrogen and sulfur fertilization (accurately + uniformly). Alternatively Thio-Sul can be relied on as the sole fertilizer to meet the crop's demand for sulfur, or as a component in a mixture with UAN or liquid manure/fermentation residues. For starter applications it is possible to add KTS (potassium thiosulfate) as a potassium source or P-Sure (ammonium polyphosphate) as a phosphorus source. In such cases speak to your Tessenderlo Kerley International agronomist.

CROP	THIO-SUL AND UAN 32 % IN BLEND	DOSE L/HA/ APPLICATION (MAX)	APPLICATION METHOD	FREQUENCY OF APPLICATION AND TIMING	OBSERVATIONS/ PRECAUTIONS
Winter and spring cereals	10% to 25% Thio-Sul + 75% to 90% UAN 32	280	Before sowing: broadcasting After sowing: topdressing, sprayer with special tubes, injection in the soil, UAN nozzle, fertigation	2 to 4, as per farm nitrogen fertilisation plan, before sowing to BBCH 51, after harvesting	Max 100 liters per irrigation set and after harvesting, 10-14 days between applications. Avoid contact with the leaves in the advanced vegetative periods.
Oilseed Rape	20% to 30% Thio-Sul + 70% to 80% UAN 32	280	Before sowing: broadcasting After sowing: topdressing, sprayer with special tubes, injection in the soil, UAN nozzle, fertigation	1 to 4, as per farm nitrogen fertilisation plan, before sowing to BBCH 50, after harvesting	Max 100 liters per irrigation set and after harvesting, 10-14 days between applications. Avoid contact with the leaves in the advanced vegetative periods.
Corn	10% to 25% Thio-Sul + 75% to 90% UAN 32	250 150 250 250	Before sowing: (broadcasting, banding) Starter (5x5) After sowing before crop emergence: soil injected, sidedressing, fertigation In vegetation: soil injected, sidedressing, fertigation	1 to 4, as per farm nitrogen fertilisation plan, Before sowing to BBCH 50, after harvesting	Max 100 liters per irrigation set and after harvesting, for the rest of application methods avoid contact with the seeds/leaves, 10-14 days between applications
Sunflower	20% to 30% Thio-Sul + 70% to 80% UAN 32	250 150 250 250	Before sowing: (broadcasting, banding) Starter (5x5) After sowing before crop emergence: soil injected, sidedressing, fertigation In vegetation: soil injected, sidedressing, fertigation	1 to 4, as per farm nitrogen fertilisation plan, before sowing to BBCH 50, after harvesting	Max 100 liters per irrigation set and after harvesting, for the rest of application methods avoid contact with the seeds/leaves, 10-14 days between applications
Soybean	20% to 30% Thio-Sul + 70% to 80% UAN 32	250 150 250 250	Before sowing: (broadcasting, banding) Starter (5x5) After sowing before crop emergence: soil injected, sidedressing, fertigation In vegetation: soil injected, sidedressing, fertigation	1 to 3, as per farm nitrogen fertilisation plan, before sowing to BBCH 79, after harvesting	Max 100 liters per irrigation set and after harvesting, for the rest of application methods avoid contact with the seeds/leaves, 10-14 days between applications
Sugarbeet	10% to 25% Thio-Sul + 75% to 90% UAN	250 150 250 250	Before sowing: (broadcasting, banding) Starter (5x5) After sowing before crop emergence: soil injected, sidedressing, fertigation In vegetation: soil injected, sidedressing, fertigation	1 to 3, as per farm nitrogen fertilisation plan, before sowing to “row closing”	max 100 liters per irrigation set and after harvesting, for the rest of application methods avoid contact with the seeds/leaves, 10-14 days between applications
Potatoes	10% to 25% Thio-Sul + 75% to 90% UAN	250 150 250 250	Before sowing: (broadcasting, banding) Starter (5x5) After sowing before crop emergence: soil injected, sidedressing, fertigation In vegetation: soil injected, sidedressing, fertigation	1 to 4, as per farm nitrogen fertilisation plan, before sowing to flowering	Max 100 liters per irrigation set and after harvesting, for the rest of application methods avoid contact with the tubers/leaves, 10-14 days between applications
Buckwheat, Linseed	10% to 25% Thio-Sul + 75% to 90% UAN	250	Before sowing: broadcasting After sowing before crop emergence In vegetation: topdressing with special UAN tubes/equipment, fertigation	1 to 3, as per farm nitrogen fertilisation plan, before sowing to flowering	Max 100 liters per irrigation set and after harvesting, for the rest of application methods avoid contact with the seeds/leaves, 10-14 days between applications
Grassland, Alfalfa	15% to 40% Thio-Sul + 60% to 85% UAN	250	Start of vegtative growth: topdressing with special UAN tubes/equipment) After cutting/grazing: topdressing with special UAN tubes/ equipments	1 to 3, as per farm nitrogen fertilisation plan	None
Vegetables (high sulfur requirement)	10% to 25% Thio-Sul + 75% to 90% UAN	40-50	At planting/drilling: soil injected, sidedressing, fertigation	Single application at planting/ drilling	Avoid contact with the seeds/ leaves

Precautions

- For 5x5 cm starter application max 150 liters/ha of the Thio-Sul and UAN blend.
- If injection applications are made close to the row (less than 30 cm), reduce application rate. Avoid root pruning.
- Do not top-dress when temperatures are above 25°C and relative humidity is below 30%.
- Rates will vary depending on crop requirement and soil analysis.
- Do not apply when crops are experiencing heat or moisture stress.

THIO-SUL IN COMBINATION WITH LIQUID MANURE

Thio-Sul can also be used in combination with liquid manures to bring the nitrogen/sulfur ratio into balance and to potentially improve nitrogen use efficiency. The exact quantities of Thio-Sul to be used in mixture with liquid manures will vary considerably depending on a number of factors including:

- The dry matter content in the manure.
- The nutrient content of the manure (specifically nitrogen an sulfur).

Typically the amount of Thio-Sul to apply per ha in the mixture may vary from 20 to 120 l depending on the crop and the factors above. For more information on the use of Thio-Sul with liquid manures please consult your Tessenderlo Kerley International agronomist.

ADDITIONAL INFORMATION

STRAW DECOMPOSITION

Thio-Sul may be used as an aid to straw decomposition. The effectiveness depends on the time of application, soil moisture and spray coverage on the straw. While temperatures are still warm, lightly disc or chisel the ground after harvest and application. Spray a mixture of Thio-Sul and UAN solution over the stubble. If possible wait at least 6 weeks before another field cultivation. Apply up to 50 liters of Thio-Sul per hectare. Thio-Sul should be mixed in enough water or UAN/water solution to supply a minimum of 190 liters of spray solution per hectare. To be effective, thorough spray coverage of the straw is essential.

SOIL PH AND CROP PRODUCTIVITY

Soil pH has a direct effect on nutrient availability as well as soil microbial activity. A low soil pH can indicate the presence of high levels of toxic ions such as manganese, iron and/or aluminum while a high pH can indicate the presence of free lime in the soil. Most crops do best with a soil pH between 6.0 and 7.5 for optimum nutrient uptake.

Periodic testing of soils using lab analysis is the only way to determine soil pH and the appropriate course of action to maintain soils at their full productive potential. Take care when applying Thio-Sul in high concentrations if the pH of the soil is below 6.0.

PRECAUTIONS FOR USE

CAUTION: plant and leaf injury may occur on some crops when certain weather and growing conditions are present. The user assumes all risks of use and handling.

- DO NOT apply Thio-Sul to foliage of crops sensitive (foliar burn) to sulfur.
- Use caution when applying fertilizer to crops experiencing extreme heat or moisture stress. Fertilizers are salts, which compete with the crop for water. Crops should be hydrated before applying any fertilizer.
- The total rate of fertilizer applied should be split among several irrigations and/or at lower rates per application as temperatures increase.
- DO NOT apply Thio-Sul with knife injectors or other types of fertilizer injecting equipment that may cause root pruning.
- DO NOT apply Thio-Sul while chlorinating irrigation system. Thio-Sul will neutralize chlorine.
- Do NOT mix Thio-Sul with acid or acidic fertilizers below a pH of 6.0.
- Avoid injecting acids into irrigation water while injecting Thio-Sul. If the water pH is below 6.0 or the injection point to close, the product could decompose and potentially plug drip system.
- Recommendations are for Thio-Sul only; the addition of other fertilizers at or near the same time could increase the chance of phytotoxicity to the crop. Please allow a minimum of 7 days between injections.
- DO NOT apply Thio-Sul directly on or below germinating seeds.
- The application of Thio-Sul for purposes other than listed herein is not recommended.
- Application of Thio-Sul by sprinklers should be followed by 1 to 2 hours of additional irrigation to reduce the possibility of fertilizer injury.
- Always apply Thio-Sul with a full irrigation and avoid application during mid-day when temperatures are high.
- Center pivot application of Thio-Sul at recommended rates should be diluted with enough water to ensure that there is no risk of that foliar burning.
- DO NOT top-dress (by airplane or ground rig) with Thio-Sul when temperatures are above 20°C and relative humidity is below 30%.
- Some foliar burn may occur even under the best of conditions.
- When working with a new formulation or application method always do a small test plot before treating the whole field.
- A jar test is recommended when mixing with pesticides to check for physical compatibility.
- When mixing Thio-Sul or any liquid fertilizer with pesticides, always keep agitators running during filling and spraying operations. Failure to maintain agitation may cause separation of products resulting in uneven spray application, which may result in phytotoxicity occurring on the crop.
- Fertigation application of Thio-Sul and other liquid fertilizers to an established crop may cause injury to a crop if:

    1. Injection period is less than 60 minutes, which may cause an uneven distribution of Thio-Sul to the crop
    2. Thio-Sul rates are higher than suggested
    3. Ample irrigation water is not applied immediately before and after the injection of Thio-Sul

- Crop injury may result from unusual weather conditions (heat wave, drought, or hot drying wind), or improper application practices such as injecting fertilizer to quickly all of which are out of control of the manufacturer or seller.
- DO NOT apply Thio-Sul in drip or micro-irrigation systems where calcium and magnesium levels in irrigation water are greater than 100 ppm due to potential plugging of emitters.
- For further information contact a Certified Crop Advisor (CCA), Pest Control Advisor (PCA), fertilizer dealer or Tessenderlo Kerley International Specialist.
- Do not apply as a foliar spray on trees or vegetable crops.

Always respect and comply with local legislation and regulation regarding the use of fertilizer products.

GENERAL PRECAUTIONS

Avoid prolonged or repeated contact with eyes, skin and clothing. Chemical goggles or a full face shield should be worn. To protect skin, wear appropriate protective equipment such as rubber or plastic aprons, rubber gloves and boots. Avoid breathing mist or vapour. Keep containers closed. Wash thoroughly after handling. May cause gastrointestinal distress if swallowed. For further information, consult a Material Safety Data Sheet (MSDS). To request an MSDS, send an e-mail tessenderlokerley@tessenderlo.com.

First aid
In case of contact with eyes, immediately flush eyes with water for at least 15 minutes. Seek immediate medical attention if irritation occurs. In case of skin contact, flush skin with water. If irritation occurs, seek immediate medical attention. Remove and wash contaminated clothing before reuse. If swallowed, give large amounts of water and induce vomiting by touching back of throat with finger unless unconscious. Seek immediate medical attention.

Handling and storage
Minimize skin exposure. Store mini-bulks and smaller containers out of the sun in an area of moderate temperature. Do not reuse containers. Avoid containers, piping or fittings made of copper containing alloys or galvanized metal. Do not store at temperatures below 8°C as crystallization may occur. Thio-Sul may be stored in plastic, fiberglass or stainless steel vessels. Dispose of containers in accordance with local regulations and requirements.

In case of spill
Contain spill and maximize recovery. Keep spill out of water sources. Exercise caution in area of spill for slippery conditions. Dispose of spilled material in accordance with regulatory requirements.

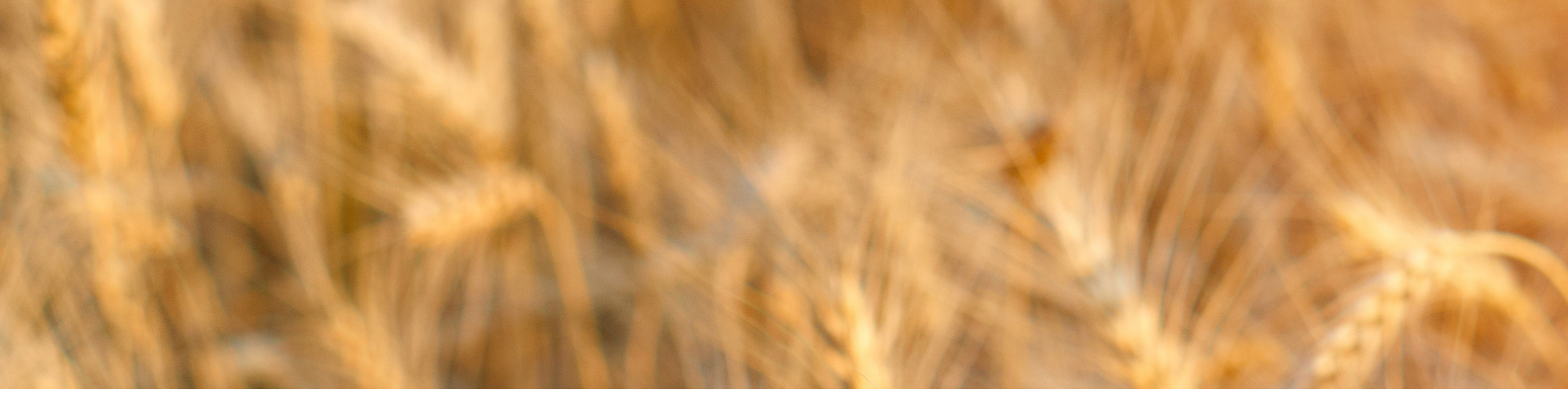
Phytotoxicity
Plant and leaf injury may occur on some crops when certain weather and growing conditions are present. The user assumes all risks of use and handling. Before handling this product, consult the MSDS for handling, safety and first aid information.

Warranty and Limitation of Damages
Crop injury may result from unusual weather conditions, failure to follow label directions, or improper application practices, all of which are out of control of the manufacturer or seller. The directions in this application guide are believed to be reliable and should be followed carefully.

While every care has been taken to ensure that the information in this publication is correct at the time of publication, Tessenderlo Group cannot give any guarantee as to its accuracy or accept any liability resulting from its use.

The purpose of this guide is to provide information about this product and to make suggestions regarding its use. This guide does not make recommendations about the amount of potassium and sulfur needed for optimum crop production. The rate of each application of Thio-Sul should be made based on a soil test, soil release rate test and/or plant tissue analysis for potassium and sulfur, and on the recommendations of a Certified Crop Advisor, Pest Control Advisor or authorized Thio-Sul distributor.

Seller's guarantee shall be limited to the terms in the Application Guide, and subject thereto, the buyer assumes any risk to person or property arising out of use or handling and accepts the product on these conditions.



SUSTAINABLE CROP NUTRITION FOR AGRICULTURE

For over 100 years Tessenderlo Kerley International has demonstrated its commitment to nurturing crop life through innovation, research and the development of novel fertilizers for a more sustainable agriculture. Our diverse product portfolio addresses the challenges of modern agriculture by delivering essential nutrients in forms that protect soil health and optimize nutrient use efficiency.

We provide an extensive range of both liquid and solid/soluble fertilizers

KTS® CaTs®

HIGH-PERFORMANCE LIQUIDS

SoluPotasse® Solucros®

HIGH QUALITY SOLID/SOLUBLES

P-Sure® Thio-Sul®

K-Leaf® GranuPotasse®

Our experts are familiar with your region and crops.
Their support includes:

- Agronomic advice
- Providing technical information
- Carrying out field studies that are specific to your issues
- Providing application and storage tips

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