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Measurement of Hydrogen Sulfide in Beef Cattle Feedlots on the Texas High Plains

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Abstract. *Hydrogen Sulfide (H_2S) is a product of anaerobic breakdown of organic materials. In enclosed facilities, this can be potentially deadly both to livestock and to human workers. Little is known about H_2S emissions from open lot feedyards. Three commercial feedyards in the Texas High Plains were selected for a one-year trial. These were well isolated from other facilities, and were categorized as small, medium, and large based on capacity. Total Reduced Sulfur (TRS) was measured once per week at each feedyard using a 631X Jerome Meter. Measurements were taken upwind, downwind of the pens, and downwind of the retention pond. Four readings were taken at each location at a height of 1 meter, and averaged. Mean concentrations upwind of the yard were 5, 5, and 6 ppb (smallest to largest yard resp.). Mean concentrations downwind of the pens were 20, 19, and 25 ppb (smallest to largest yard resp.). Mean concentrations downwind of the retention ponds were 13, 10, and 96 ppb (smallest to largest yard resp.).*

Keywords. Hydrogen Sulfide, beef cattle, open lot, feedyard, feedlot, Jerome Meter

Introduction

Hydrogen Sulfide (H_2S) is a colorless gas with a characteristic "rotten-egg" odor. H_2S has been recognized as a health hazard for workers in confined areas. The National Institute for Occupational Safety and Health (NIOSH) has set exposure limits for workers at 10 ppm per 10 minutes (1997). For exposures above this, NIOSH recommends supplied air sources for breathing. NIOSH further warns that, while the characteristic odor associated with H_2S is present in lower concentrations, the human nose can become rapidly fatigued and should not be relied upon to warn of the continuous presence of H_2S. H_2S is also heavier than air, so it will tend to collect in low areas. This can be of concern to workers in enclosed areas such as swine or dairy barns. Most research with H_2S has been done in swine facilities due to the risk involved both with animals and with human workers.

The Texas Administrative Code Title 30 Part I Chapter 12 Subchapter B Rule §112.32 states "No person may cause, suffer, allow, or permit emissions of hydrogen sulfide from a source or sources operated on a property or multiple sources operated on contiguous properties to exceed a net ground level concentration of 0.12 ppm averaged over any 30-minute period if the downwind concentration of hydrogen sulfide affects only property used for other than residential, recreational, business, or commercial purposes, such as industrial property and vacant tracts and range lands not normally occupied by people." This rule applies to concentrated animal feeding operations (CAFO's) including feedyards.

There are several methods for measurement of H_2S. These include diffusion tubes, which measure concentrations 1,000 ppb and greater, MDA single point monitors, which measure concentrations 2-90 ppb, and Jerome meters, which have a range of 3 ppb to 50 ppm. The Jerome meter is a portable device which actually measures total reduced sulfur (TRS) compounds, and reports these as H_2S.

However, very little work has been done to characterize H_2S at beef cattle feedyards. Koelsch et al (2002) found that TRS concentrations in the center of Nebraska feedyards to ranged from 0.001 to 0.0037 ppm, while concentrations at the holding pond ranged from 0.005 - 0.012 ppm.

H_2S is produced by the anaerobic degradation of sulfur compounds. For this to occur, sulfur must be introduced to the feedyard. This is typically done via the feedstuffs fed to animals. Methionine and cystine are two amino acids found in common feedyard diets, and account for most of the sulfur introduced to the animal (Goodrich and Garret, 1986). Sulfur content of common feeds as percent dry matter is 0.12 for corn, 0.13 for corn silage, 0.46 for distillers grain, and 0.43 for cottonseed meal (NRC, 1982). Sulfur is required in the diets of growing-finishing cattle at the NRC rates of 0.10% of dry matter intake (1984).

The objectives of the study were to:

1. Characterize H_2S concentrations as total reduced sulfur at commercial open lot beef cattle feedyards.
2. Determine if correlations between TRS and ambient weather conditions existed, and
3. Determine if a correlation between TRS and odor DT's existed

Methods and Materials

TRS Measurements

Three commercial beef cattle feedyards were selected in the Texas Panhandle. Feedyards were labeled as A, B, and C, with A having the smallest onetime feeding capacity and C having the largest. Feedyard capacities ranged from 25,000 to 55,000 head. Total Reduced Sulfer (TRS) readings were taken using a Jerome 631-X Hydrogen Sulfide Analyzer (Arizona Instruments). The Jerome Meter reports TRS as H_2S. The range of the Jerome 631-X is 5 ppb to 50 ppm H_2S.

Three to four measurements were taken at each feedyard once per week for one year and averaged. Measurement locations were based on wind direction. Locations were upwind of the pens at the feedyard property line, downwind of the pens at the property line, and about 20 m downwind of the retention pond.

Odor Sample Collection and Detection Threshold

Odor samples were taken at the same locations and times as the H_2S readings (Parker et al, 2003). These were taken in 10 L Tedlar® bags using a vacuum chamber. The odor samples were returned to the WTAMU Olfactometry Lab for DT analysis by a trained odor panel. DT was determined by use of an AC'Scent International Olfactometer (St. Croix Sensory, Lake Elmo, MN) and DT'S were calculated following guidelines of ASTM (1991). The DT for each individual panelist was calculated as the geometric mean of the concentration at which the last incorrect guess occurred and the next higher concentration at which the odor was correctly detected. The final DT was calculated as the geometric mean of the individual panelist DT's (Parker et al, 2003).

Manure Moisture Samples

Manure samples were collected from within two pens at each feedyard. Manure was collected at three locations within each pen (Figure 1), within 3 m of the bunk pad, the center of the pen (or mound) and within 6 m of the rear fence of the pen. Samples were collected at two depths at each location, the loose surface material which varied in depth from about 2-5 cm in thickness, and the hardpack subsurface manure of about 2-10 cm depth. Samples were oven dried at 100 C for 24 hrs to determine gravimetric moisture content on a wet weight basis.

Weather Data

Climatic data was collected from stationary Unidata weather stations located at the southwest corner of each feedyard. This was based on the predominant wind direction for the area. Data was collected every 2 minutes (average of 15 second readings), stored in a Starlogger datalogger, and downloaded weekly. Data included air temperature, wind speed, wind direction, rainfall, solar radiation, and soil temperatures at 5 and 15 cm depths.

Jerome Meter Quality Assurance

The Jerome meter was sent to the Idaho State Department of Agriculture to be audited and checked against a calibration gas. This was to determine both precision and accuracy in the meter. The Jerome meter was within a 10% error on all concentrations tested, and in most cases within 5% (Table 1). Error was determined by taking ten readings with the meter, averaging them, and comparing the mean to the standard gas.

Results and Discussion

TRS Concentrations

TRS concentrations were not widely varied across feedyard or location, with the exception of the retention pond at Feedyard C, which had a higher mean than the other 2 feedyards. Concentrations downwind of the pens were higher than reported for 3 Nebraska feedyards (Koelsch et al, 2002). The Texas feedyards had larger capacities than did the Nebraska feedyards. This indicates that fetch, or length across the yard, may play a role in TRS concentrations.

TRS Concentrations vs. DT

Correlations were found between odor detection threshold and TRS concentrations downwind of he pens and downwind of the pond (table 4). R-squares were 0.04, 0.17, and 0.03 for locations downwind of the pens, downwind of the ponds, and upwind, respectively (figs 2-4). TRS concentrations downwind of both the pens and the ponds tended to have positive correlations, although neither were significant (table 4). TRS concentrations upwind of the feedyard had a negative correlation with DT (Table 4) and were not significant.

TRS Concentrations v. Climatic Data and Manure Moisutre

Pearson product correlations were established for all TRS concentrations vs. weather data and manure moisture content. No significant (α=0.05) correlations were found for TRS of upwind locations or downwind of the retention ponds. Both manure surface moisture and manure pack moisture had positive correlations with TRS concentrations downwind of the pens (Table 3). Surface manure moisture content had an R-square of 0.16 with TRS across all 3 feedyards, while the manure pack moisture content had an R-square of 0.11 (fig. 5 &6). Rainfall events were not considered for this study, as it was assumed that % manure moisture would reflect this. Koelsch et al (2002) reported a linear increase of TRS with increasing temperature. However, the results here indicated a decrease in TRS concentrations downwind of the pens as air temperature increased (fig 7). The majority of the readings were taken between 15° and 35° C, and are point measurements, not continuous, but an R-square of 0.12 was recorded. Solar radiation had no correlation (R-square = 0.003) with TRS, although a slight downward trend was noticed (Fig 8). Both 5 and 15 cm soil depth temperatures showed a decrease in TRS concentrations with an increase in temperature (figs 9 & 10). Both also had an R-Square of about 0.21. Wind speed was anticipated to reduce TRS concentrations. We felt a greater wind speed would create a diluting effect, thus causing lower readings. Although there was no correlation, wind speed tended to have the opposite effect and actually showed a slight increase in TRS concentrations (fig 11).

Conclusions

1. Mean H_2S concentrations at these beef cattle feedyards were below the regulatory rates for the state of Texas. Only one data point exceeded 1 ppm. Concentrations of H_2S as TRS were approximately equal for all feedyards downwind of the pens regardless of feedyard size.
2. Significant ($p < 0.001$) positive correlations were found for the moisture content of both the surface manure and the manure pack. Significant ($p < 0.001$) negative correlations were found for the ambient air temperature, the 5 cm soil depth temperature, and the 15 cm soil depth temperature.
3. There were no correlations between TRS and upwind DT's. There was a slight positive correlation between TRS and downwind pen DT's ($p = 0.035$). There was a positive correlation between TRS and downwind pond DT's ($p < 0.001$).

Table 1: Audit Results of Jerome Meter v. TECO against a standard Calibration Gas

		Target Gas Concentration (ppb)			
		44	44	77	371
Jerome Meter	Reading	44.9	47.8	78.3	352
	Difference	2%	9%	2%	-5%

Table 2: Mean Concentrations of TRS by Feedyard and Location

Feedyard	Sample Location	Mean	Std. Deviation	N
A	Upwind	0.006	0.003	39
	Downwind Pens	0.026	0.023	40
	Downwind Pond	0.014	0.020	39
B	Upwind	0.010	0.026	37
	Downwind Pens	0.021	0.015	38
	Downwind Pond	0.010	0.006	35
C	Upwind	0.005	0.003	44
	Downwind Pens	0.029	0.028	41
	Downwind Pond	0.087	0.176	39
Total	Upwind	0.007	0.014	120
	Downwind Pens	0.025	0.023	118
	Downwind Pond	0.038	0.109	114

Table 3: Pearson Product Correlations for TRS Downwind of the Pens vs Climatic Data and Manure Moisture Content

	Pearson Correlation	P (2-Tailed)	N
Manure Surface MC	0.40	< 0.001*	110
Manure Pack - MC	0.33	< 0.001*	113
Air Temp	-0.35	< 0.001*	109
5 cm Soil Temp	-0.46	< 0.001*	113
15 cm Soil Temp	-0.46	< 0.001*	113
Solar Radiation	-0.05	0.567	113
Wind Speed	0.06	0.520	113
Panel Detection Threshold	0.21	0.035*	104

*correlations are significant at α=0.05

Table 4: Pearson Product Correlations for Panel Detection Threshold vs. TRS

	TRS		
	Pearson Correlation	P (2-Tailed)	N
Upwind PDT	-0.16	0.102	106
Downwind Pens PDT	0.21	0.035*	104
Downwind Ponds PDT	0.41	< 0.001*	102

*correlations are significant at α=0.05

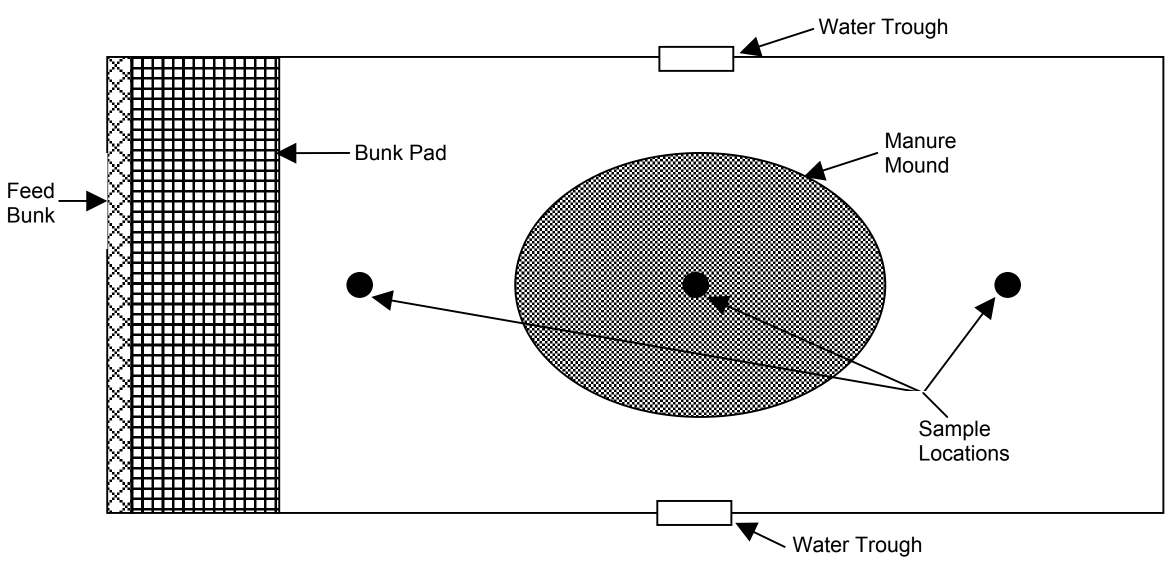

Figure 1: Pen schematic showing relative location of pen features and manure sampling locations.

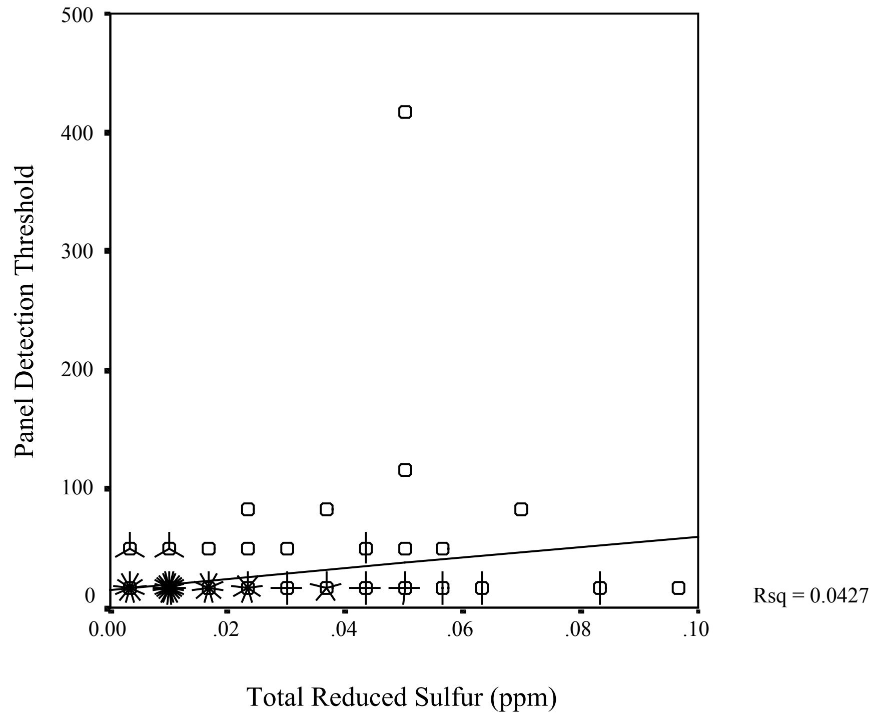

Figure 2: TRS v DT Downwind of pens

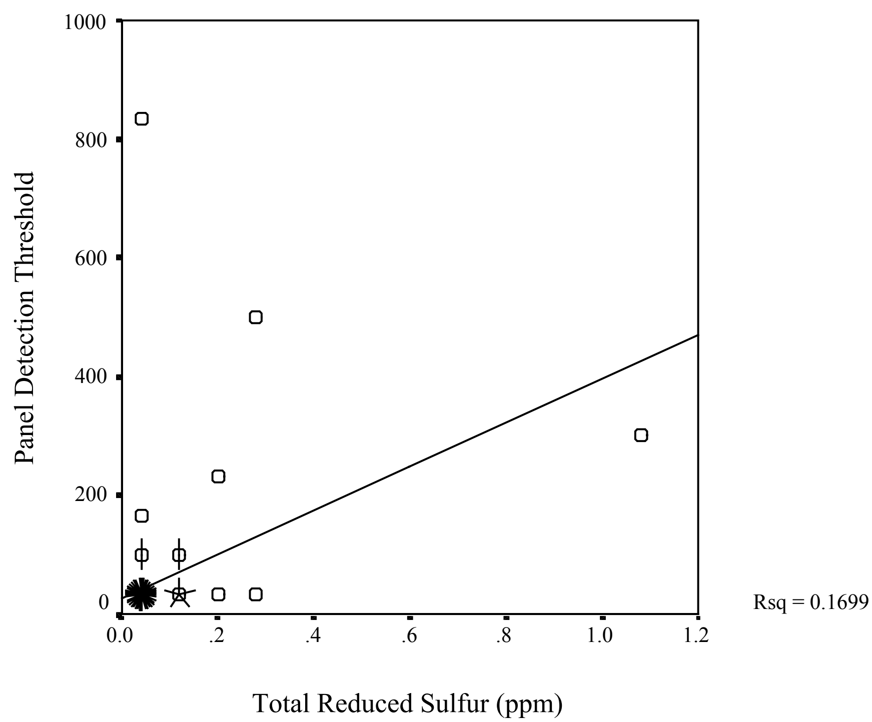

Figure 3: TRS v. DT downwind of ponds. The number of petals indicate the number of points at a particular level.

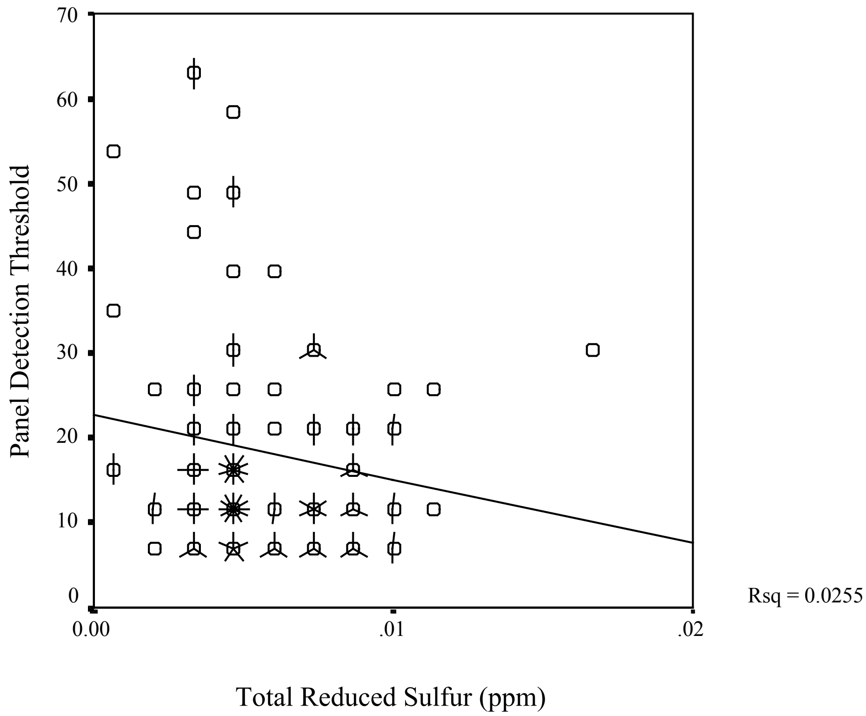

Figure 4: TRS v DT upwind of the feedyards. The number of petals indicate the number of points at a particular level.

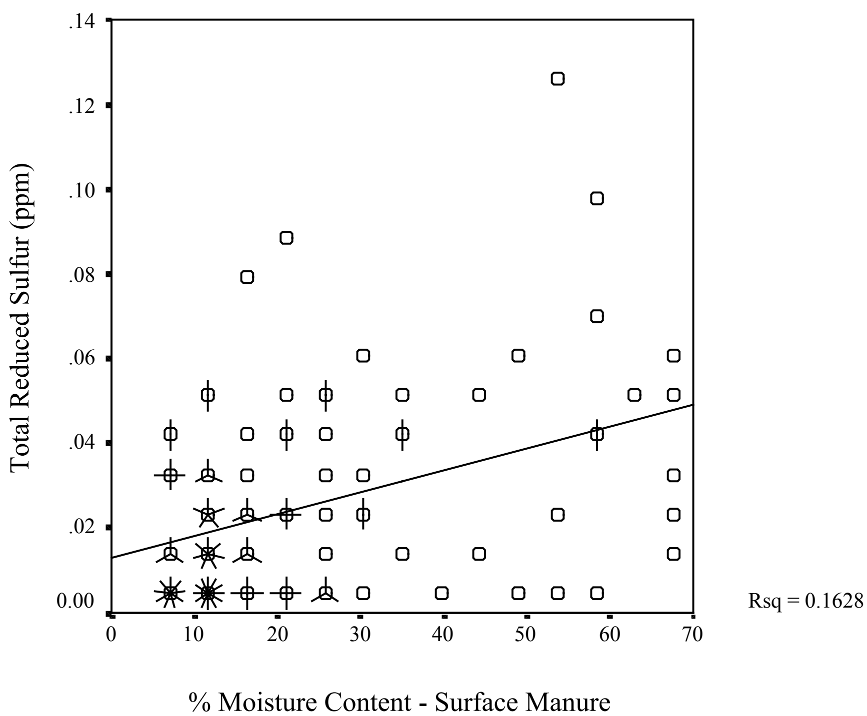

Figure 5: TRS v Surface Manure Moisture Content. The petals per point indicate occurrences at that level.

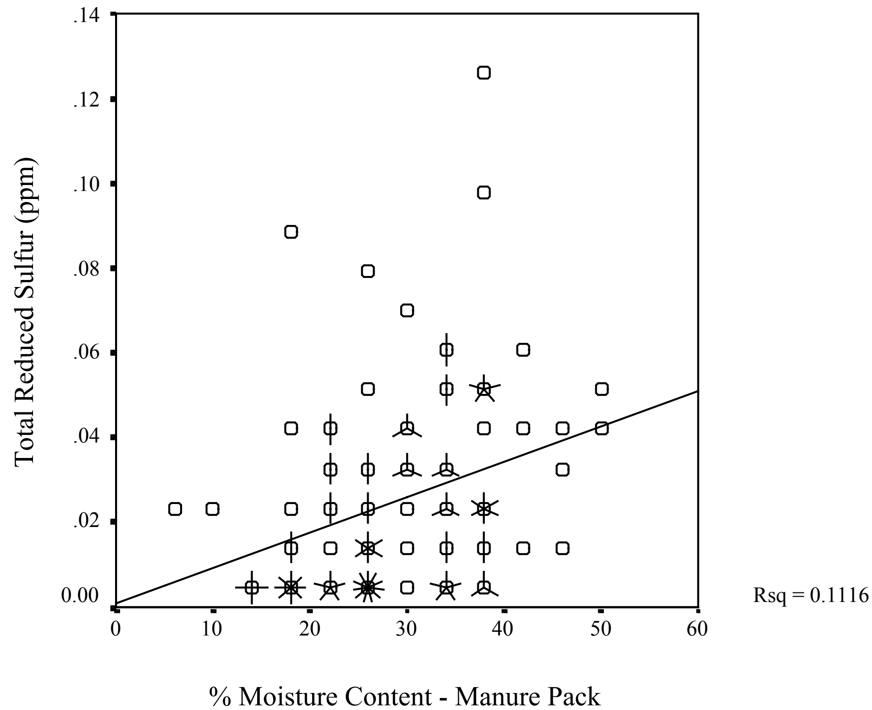

Figure 6: TRS v. Manure Pack Moisture Content. The petals per point indicate occurrences at that level.

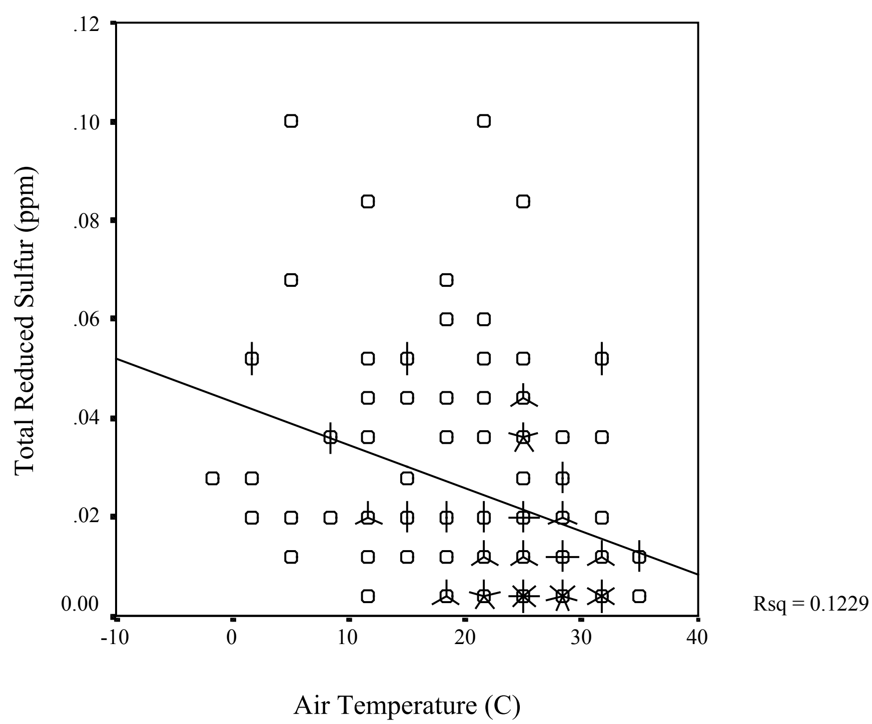

Figure 7: TRS v Ambient Air Temperature at time of Sampling. The petals per point indicate occurrences at that level.

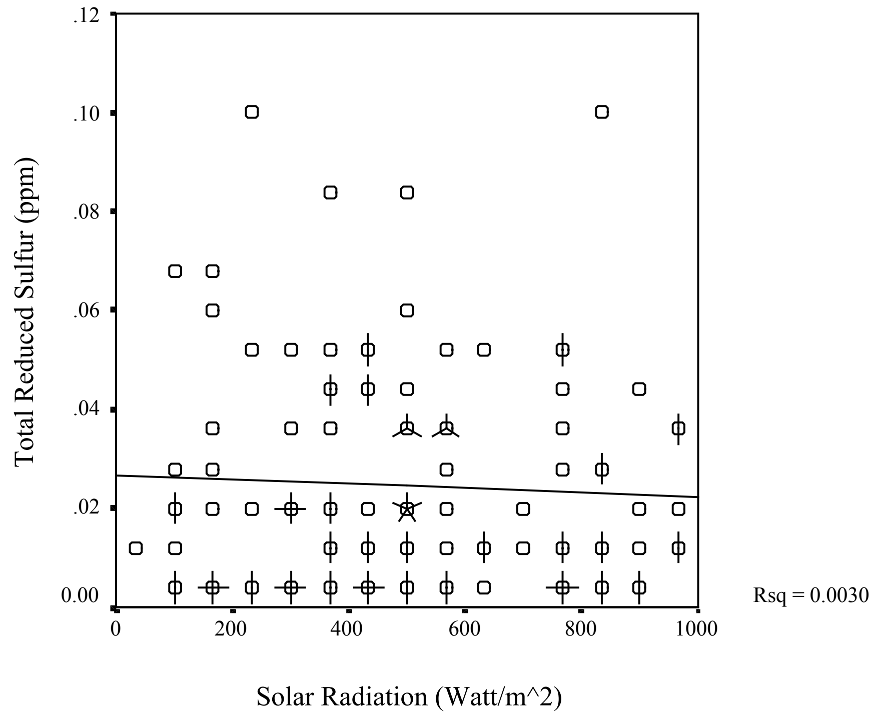

Figure 8: TRS v Solar Radiation at time of Sampling. The petals per point indicate occurrences at that level.

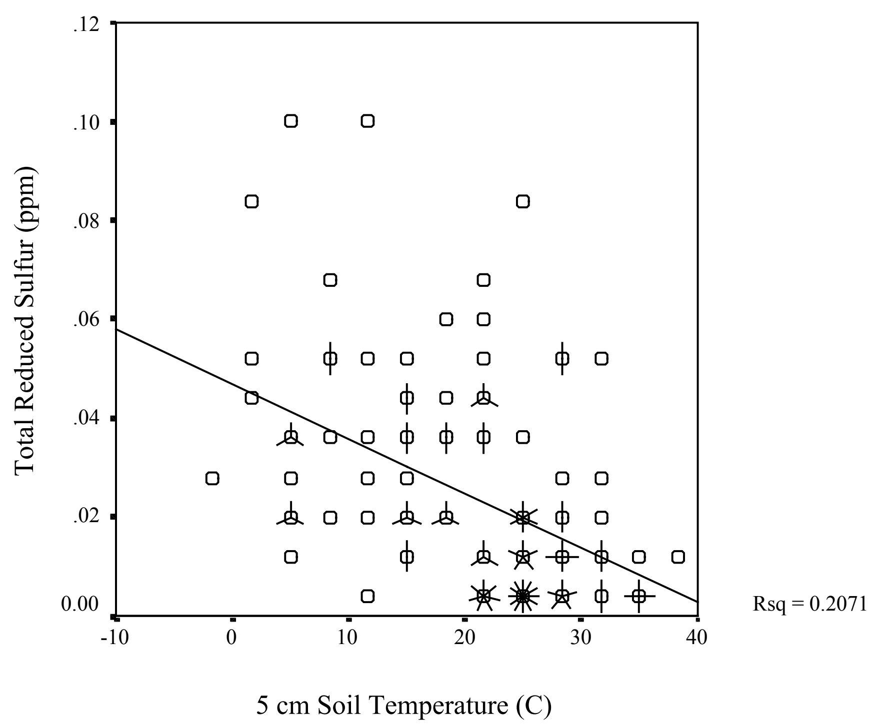

Figure 9: 5 cm Soil Temperature (°C) v TRS. The petals per point indicate occurrences at that level.

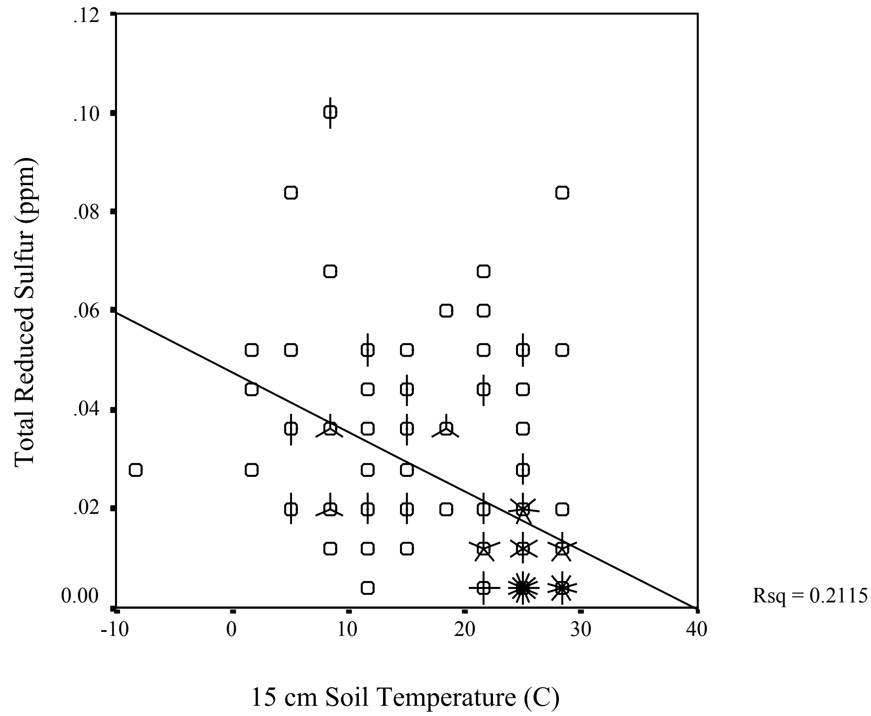

Figure 10: TRS v. 15 cm Soil Temperature (°C). The petals per point indicate occurrences at that level.

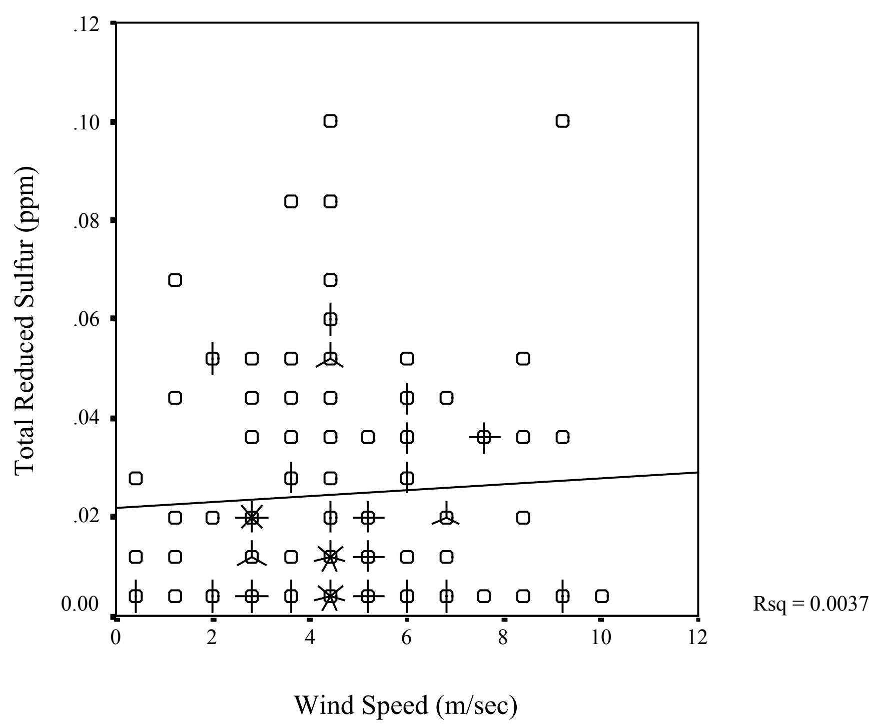

Figure 11: TRS v Wind Speed. The petals per point indicate occurrences at that level.

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