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Nitrogen and Sulfur Fertilization Influences Aromatic Flavor Components in *Shrunken2* Sweet Corn Kernels

Adamson D. Wang[1], **John M. Swiader**[2], **and John A. Juvik**[3]
Department of Horticulture, University of Illinois, Urbana, IL 61801

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Abstract. **Dimethyl sulfide (DMS) has been identified as the compound responsible for the characteristic aroma of cooked sweet corn *(Zea mays* L.) and, along with sugar and water-soluble polysaccharides, is one of the main flavor components in the kernels. Because of the close relationship between DMS and its amino acid precursor S-methylmethionine, the premise was formulated that it might be possible to improve sweet corn aroma and overall eating quality through enhanced production of DMS from increased application of N and S to the crop in the field. Studies were conducted on a Plainfield sand and a Flanagan silt loam to evaluate the effects of N and S fertilization on kernel DMS production in several commercial *sh2* hybrids; in the process, the effect of N and S fertilization on various yield and yield component parameters was also determined. Hybrid was the main factor affecting kernel DMS production, although in both soils kernel DMS levels were influenced by significant interactions between hybrid and fertilizer treatments. Kernel DMS content, in response to increasing N fertilization rates, increased by an average of 85% in three of six hybrids in the Plainfield sand and by 60% in two of three hybrids in the Flanagan silt loam. The effect of S fertilization on kernel DMS production was small, with only one hybrid on the sandy soil showing a positive response (38%) to S application, and then in combination with high N rates. Irrespective of N-S fertilization regime, kernel DMS concentrations decreased at both locations by an average of ≈8.5% per day as kernel maturity increased. The results showed that kernel DMS production may be enhanced by N nutrition, independent of N fertilization effects on ear and kernel yields.**

The importance of flavor in consumer acceptance of sweet corn is well documented, with the three most important components of overall flavor response consisting of sweetness, texture, and aroma (Flora and Wiley, 1974a). While sweetness, or taste, is closely related to kernel sucrose content, and texture depends on several factors including pericarp tenderness, moisture content, and the levels of water soluble polysaccharides (WSP), aroma is most often associated with the kernel content of dimethyl sulfide (DMS) (Wiley, 1985). Acting through a heat-labile S-containing amino acid precursor, S-methylmethionine sulfonium salt (MMS), DMS is the compound responsible for the characteristic odor of cooked sweet corn (Bills and Keenan, 1968; Williams and Nelson, 1974). Although not as easily defined as either sweetness or texture, sensory evaluation studies have shown that aroma can contribute between 15% and 33% of the overall flavor response in sweet corn (Flora and Wiley, 1974a; Wong et al., 1995).

Recently, sweet corn breeders have been very successful in developing new cultivars that have elevated levels of sugar and WSPs in the kernels, however, very little attention has been given to improving aroma. Several studies have reported significant differences in kernel DMS production among sweet corn genotypes and harvest maturities, with DMS content decreasing with increasing kernel age (Dignan and Wiley, 1976; Flora and Wiley, 1974b). In screening 24 commercial *sh2* hybrids for various kernel quality components, kernel DMS showed the greatest reduction with kernel age, decreasing an average of 9%/day 20 to 29 days after pollination (Wong et al., 1994). This decrease in kernel DMS content with increasing kernel maturity is of major concern to the sweet corn processing industry due to the potential for substantial loss of aromatic quality of the cooked product.

Because of the close relationship between DMS and MMS, the premise was formulated that it might be possible to enhance sweet corn aroma and overall eating quality through increased production of DMS from increased applications of N and S fertilizer to the crop in the field. Previous research, using a variety of plant species, has reported N-S fertilizer interactions on crop yield (Janzen and Bettany, 1984), nutrient uptake (Rasmussen et al., 1975), and various crop quality characteristics including the amino acid composition in wheat (Byers and Bolton, 1979) and barley (Eppendorfer, 1968), where a synergistic effect was found between N and S fertilization rates on cysteine and methionine content in grain of both crops. The positive interaction between N and S application on amino acid production has been attributed to the interdependence of N and S nutrition in various reduction pathways of amino acid metabolism (Giovanelli, 1987). Although N and S fertilization may not affect crop yields, the application of either or both may increase the levels of S-containing amino acids in the seed (Joseffson, 1970) and, hence, the DMS potential of the kernels.

The objective of this study was to determine the effect of N and S fertilization on kernel DMS production in *sh2* sweet corn hybrids over a range of harvest maturities. This study also evaluated the effect of N and S fertilization on various sweet corn yield and yield component parameters. By conducting the research at two locations with distinct soil types, we were able to assess the response in kernel DMS and yield-related traits to N-S fertilization under markedly different soil conditions similar to those in the major sweet corn production regions in Illinois.

Materials and Methods

Field design. In 1990, a factorial combination of two N rates (168 and 310 kg·ha^{-1}) and three S rates (0, 34, 101 kg·ha^{-1}) was applied to six *sh2* sweet corn hybrids ('Crisp-N-Sweet 710', 'FMX 263', 'Summer Sweet 7210', 'Supersweet Jubilee', 'Sweetie 70',

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[1] Former graduate research assistant; presently post-doctoral candidate.

[2] Associate professor; to whom reprint requests should be addressed.

[3] Professor.

and ‘Sweetie 82’) in a Plainfield sand (mixed, mesic Typic Udipsamment) at the Univ. of Illinois River Valley Sand Field (IRVSF) in Kilbourne. The hybrids were selected from a previous study based on their differences in kernel DMS production potential (Wong et al., 1994). The soil at the site was characterized by low organic matter content (<1.0%) and nutrient holding capacity [cation-exchange capacity (CEC) of ≈5.0 meq/100 g soil], and is representative of many of the sandy soils used by commercial sweet corn growers in the state.

The experimental design was a split-plot, with N-S fertilizer combinations as main plots and hybrids as subplots. Nitrogen fertilizer was applied as ammonium nitrate, with two-thirds of the total N broadcast just before planting and the remaining portion sidedressed in two equal applications during the growing season when plants were 8 cm high and at tasseling. Sulfur was applied as calcium sulfate; at the intermediate rate, all S was broadcast at planting, while at the high rate, S was applied in three equal applications-at planting, when plants were 8 cm high, and at tasseling. Main plots were arranged in a completely randomized fashion with four replications, Subplots consisted of three rows of each hybrid, spaced 75 cm apart, with each row containing 21 hills spaced at 25cm intervals. Hybrids in each subplot were seeded using hand planters at a rate of one seed per hill. Germination was uniform in all plots, ranging from 90% to 95%, resulting in an approximate stand of 45,000 plants/ha. Border rows were established on the edge between main plots to minimize fertilizer carryover between treatments. Standard commercial production practices were followed throughout the growing season, including

Table 1. Effect of N and S fertilization and hybrid on sweet corn yield and yield components at 23 days after pollination at the Illinois River Valley Sand Field.

Effect	Ear uniformity (0 to 4)[z]	Ear wt (g)	Ear length (cm)	Kernel depth (cm)	Potential yield (MT·ha^{-1})	Kernel yield (MT·ha^{-1})
N–S fertilizer (kg·ha^{-1})						
168N–0S	2.5 b[y]	173.9 c	18.6	1.06 d	7.7 c	5.4 b
168N–34S	2.4 b	168.1 c	18.4	1.10 bcd	7.5 c	5.5 b
168N–101S	2.6 b	178.7 c	19.0	1.07 cd	8.0 c	5.6 b
310N–0S	2.9 a	211.6 ab	19.6	1.13 bc	9.4 ab	6.7 a
310N–34S	3.0 a	226.0 a	20.1	1.14 ab	10.0 a	7.2 a
310N–101S	2.8 a	206.0 b	19.7	1.19 a	9.2 b	6.7 a
	*	**	NS	**	**	**
Hybrid						
Crisp-N-Sweet 710	2.8 b	199.0 b	19.2 b	1.16 a	8.8 b	6.5 ab
FMX 263	2.6 b	217.0 a	20.7 a	1.16 a	9.6 a	7.1 a
Summer Sweet 7210	2.7 b	189.3 bc	19.1 b	1.13 a	8.4 bc	6.1 bc
Supersweet Jubilee	2.8 b	178.9 c	19.2 b	1.15 a	8.0 c	6.0 c
Sweetie 70	2.0 c	180.0 c	18.8 bc	0.91 b	8.0 c	4.9 d
Sweetie 82	3.3 a	200.9 b	18.5 c	1.17 a	8.9 b	6.5 ab
	**	**	**	**	**	**

[z] Rating of 0 was assigned when <10% of the harvested ears had good marketable quality, up to a rating of 4 when >90% of the harvested ears were similar in size, shape, and overall appearance.

[y] Mean separation within columns by LSD at $P = 0.05$.

NS,*,**Nonsignificant or significant ANOVA at $P = 0.05$ or 0.01, respectively.

Table 2. Effect of N and S fertilization and hybrid on sweet corn yield and yield components at 23 days after pollination at Urbana.

Effect	Ear uniformity (0 to 4)[z]	Ear wt (g)	Ear length (cm)	Kernel depth (cm)	Potential yield (MT·ha^{-1})	Kernel yield (MT·ha^{-1})
N–S fertilizer (kg·ha^{-1})						
0N–0S	3.0	231.8	20.1	1.12	10.3	7.4
0N–101S	3.0	237.5	20.2	1.10	10.6	7.5
168N–0S	3.2	247.0	20.3	1.14	11.0	7.9
168N–101S	3.2	250.3	20.2	1.14	11.1	8.0
	NS	NS	NS	NS	NS	NS
Hybrid						
Crisp-N-Sweet 710	3.1	245.1	20.5 a[y]	1.11 b	10.9	7.8
FMX 263	3.1	234.4	20.4 a	1.07 c	10.4	7.4
Sweetie 82	3.1	245.5	19.6 b	1.20 a	10.9	7.9
	NS	NS	*	**	NS	NS

[z] Rating of 0 was assigned when <10% of the harvested ears had good marketable quality, up to a rating of 4 when >90% of the harvested ears were similar in size, shape, and overall appearance.

[y] Mean separation between hybrids by LSD at $P = 0.05$.

NS,*,**Nonsignificant or significant ANOVA at $P = 0.05$ or 0.01, respectively.

using supplemental sprinkler irrigation to provide a total (including rainfall) of 3.8 cm of water per week.

The following year (1991), three *sh2* hybrids ('Crisp-N-Sweet 710', 'FMX 263', and 'Sweetie 82'), selected by their responsiveness in kernel DMS production to N-S fertilization in the 1990 study, were planted in a Flanagan silt loam (fine, montmorillonitic, mesic Aquic Argiudoll) at the South Urbana Vegetable Research Farm. In contrast to the IRVSF, this site had a fairly high (≈5.0%) organic matter content and high fertility (CEC ≈24 meq/100 g of soil). The same experimental design was used, except each subplot consisted of three rows spaced 90 cm apart, with each row containing 22 plants at 25-cm intervals. The fertilizer treatments consisted of a factorial combination of two N rates (0 and 168 $kg\cdot ha^{-1}$) and two S rates (0 and 101 $kg\cdot ha^{-1}$), supplied as ammonium nitrate and calcium sulfate, respectively. The N and S fertilizer treatments were applied in the same manner as at the IRVSF. Planting procedures and production practices, including supplemental overhead sprinkler irrigation, were similar to those used in 1990.

Table 3. Effect of N and S fertilization (F), hybrid (H), and harvest maturity [days after pollination (DAP)] on kernel dimethyl sulfide (DMS) levels at the Illinois River Valley Sand Field.

	N–S fertilizer	Kernel DMS ($\mu g\cdot g^{-1}$)			
Hybrid	($kg\cdot ha^{-1}$)	20 DAP	23 DAP	26 DAP	LSD(0.05)[z]
Crisp-N-Sweet 710	168N–0S	56.6	26.0	20.4	18.2
	168N–34S	32.9	26.7	27.6	10.5
	168N–101S	50.9	30.7	19.1	12.8
	310N–0S	136.3	95.6	75.6	32.1
	310N–34S	109.3	94.0	66.6	24.7
	310N–101S	131.2	84.6	58.3	25.5
		31.3[y]	26.3	21.7	
FMX 263	168N–0S	44.4	36.6	25.6	6.6
	168N–34S	51.7	39.0	28.8	20.7
	168N–101S	51.6	42.6	35.8	10.8
	310N–0S	43.4	34.2	30.3	11.7
	310N–34S	43.4	38.0	29.8	7.4
	310N–101S	74.5	53.9	50.9	4.4
		20.8	9.8	6.2	
Summer Sweet 7210	168N–0S	76.8	50.6	45.2	32.3
	168N–34S	105.6	60.9	50.9	44.1
	168N–101S	119.7	61.8	57.2	33.3
	310N–0S	99.6	67.0	38.0	18.7
	310N–34S	148.3	95.0	52.5	27.9
	310N–101S	118.3	76.4	60.8	34.1
		NS	NS	NS	
Supersweet Jubilee	168N–0S	49.9	27.0	27.8	9.0
	168N–34S	48.5	36.2	38.2	18.7
	168N–101S	54.8	35.5	27.9	7.2
	310N–0S	57.3	31.1	22.5	14.7
	310N–34S	58.8	23.2	28.4	12.1
	310N–101S	50.3	33.9	31.6	15.3
		NS	NS	NS	
Sweetie 70	168N–0S	102.9	62.5	51.7	25.1
	168N–34S	105.2	69.3	41.9	26.7
	168N–101S	72.4	62.9	44.1	18.6
	310N–0S	74.1	39.2	35.0	9.1
	310N–34S	71.2	46.6	26.2	17.8
	310N–101S	79.6	47.5	32.9	20.0
		31.0	NS	NS	
Sweetie 82	168N–0S	61.4	55.8	46.8	16.5
	168N–34S	83.4	59.4	35.7	22.2
	168N–101S	80.4	74.2	50.7	24.7
	310N–0S	118.5	82.2	62.0	22.1
	310N–34S	127.3	71.5	58.8	16.7
	310N–101S	106.4	69.6	55.9	20.6
		29.7	NS	15.4	
LSD(0.05)	F × H	32.6[x]	21.1	17.8	

[z] LSD between harvest maturities at $P = 0.05$.

[y] LSD between fertilizer treatments at $P = 0.05$.

[x] LSD for the interaction between N-S fertilizer treatments and hybrid at $P = 0.05$.

[NS] Nonsignificant ANOVA.

Yield and yield component evaluations. Plants in the middle row of each plot were allowed to open-pollinate, while at least 20 plants from the outside rows in each plot were self-pollinated by hand. At 23 days after pollination (DAP) of the outside rows, open-pollinated ears were harvested and evaluated for ear uniformity, ear weight, kernel depth, potential yield, and kernel yield, using the procedures of Wong et al. (1994). Potential yield was the estimated weight (t·ha^{-1}) of husked ears, assuming a stand density of 45,000 plants/ha. Kernel yield, which represents the usable yield to processors after separation of the kernels from the husks by a commercial cutting machine, was estimated by multiplying the potential yield by the proportion of kernel volume in an average ear.

Kernel chemical analyses. All ears harvested for kernel chemical analyses were hand-pollinated to ensure uniform maturity and genetic purity. At both locations, harvests for kernel DMS analysis were made at 3-day intervals from 20 to 26 DAP. These stages were chosen to represent a range of kernel maturities and to coincide with the time when sweet corn is normally harvested at ≈21 DAP (Swiader et al., 1992). In addition, an early harvest was made at 17 DAP for kernel DMS analysis at Urbana.

At each harvest date, four self-pollinated ears were picked at random for each hybrid and prepared for analysis. Kernel sampling procedures, postharvest handling, and sample preparation were carried out as described by Wong et al. (1994). Kernel DMS concentrations were assayed using a gas chromatograph and a flame ionization detector following the procedures of Breeden and Juvik (1992). In addition, kernel MMS and methionine (MET) levels were determined in ears harvested at 23 DAP at the IRVSF, according to the method of Grunau and Swiader (1991), using a gradient system (Pickering Laboratories, Mountain View, Calif.) with postcolumn ninhydrin derivatization.

Data analysis. Analysis of variance (ANOVA) was performed on the various yield, yield component, and kernel chemical criteria for each location. In each analysis there were four replications. Least significant difference (**LSD**) values calculated at the 5% level of probability were used to compare differences between N-S fertilizer rates, hybrid means, and harvest maturities, when appropriate. To estimate the relative importance of N-S fertilization and hybrid on kernel quality, the total variability for each kernel chemical aroma characteristic was partitioned into component sources of variation due to hybrid, fertilizer, hybrid by fertilizer interaction, and error term. Based on the ANOVA procedure, the sum of squares of each factor was divided by the total sum of squares in the model, and expressed as percentages.

Results and Discussion

Yield and yield components. In 1990, sweet corn yield and yield component parameters at the IRVSF were influenced by significant effects from N-S fertilizer application and hybrid (Table 1). The one exception to these results was ear length, which was not affected. by any fertilizer treatment. In each case, there were no significant interactions between N-S fertilization and hybrid, indicating that the relative response in each of the measured variables to N-S application was consistent among the six hybrids. Ear weight, potential yield, kernel yield, and ear uniformity each increased as N rate increased from 168 to 310 kg·ha^{-1}. Although S application generally had little effect on the various yield and yield component parameters, there was a decrease in ear weight and potential yield as N-S fertilization rate increased from 310N-34S to 310N-101S.

Among the six hybrids at the IRVSF, potential yield was highest in ‘FMX 263’ and lowest in ‘Supersweet Jubilee’ and ‘Sweetie 70’. Kernel yield was highest in ‘FMX 263’, ‘Crisp-N-Sweet 710’, and ‘Sweetie 82’ and lowest in ‘Sweetie 70’. Based on ear weight and length, ‘FMX 263’ produced the largest ear. Ears of ‘Sweetie 82’ were short but had relatively high weight and good uniformity, an important characteristic for the fresh-market industry. In contrast, ears of ‘Sweetie 70’ were extremely variable, with relatively poor kernel development.

In 1991, there was no significant effect of fertilizer treatment or hybrid on either potential or kernel yields at Urbana (Table 2).

Table 4. Effect of N and S fertilization (F), hybrid (H), and harvest maturity [days after pollination (DAP)] on kernel dimethyl sulfide (DMS) levels at Urbana.

Hybrid	N-S fertilizer (kg·ha^{-1})	Kernel DMS (µg·g^{-1}) 17 DAP	20 DAP	23 DAP	26 DAP	LSD(0.05)[z]
Crisp-N-Sweet 710	0N–0S	89.8	63.2	22.7	20.3	13.5
	0N–101S	97.7	58.5	25.5	17.8	10.0
	168N–0S	139.9	88.4	41.6	23.7	3.7
	168N–101S	133.3	79.7	38.3	21.8	8.8
		10.0[y]	16.5	8.7	2.3	
FMX 263	0N–0S	58.7	30.2	12.3	nd[x]	3.3
	0N–101S	40.3	11.3	7.0	6.4	3.6
	168N–0S	74.2	37.0	13.8	11.0	5.3
	168N–101S	68.2	34.4	15.3	13.0	4.9
		8.3	6.3	3.0	2.1	
Sweetie 82	0N–0S	97.2	77.4	47.6	30.3	9.2
	0N–101S	101.5	78.3	50.0	37.7	5.2
	168N–0S	98.5	70.5	46.4	26.5	10.0
	168N–101S	103.8	65.8	40.7	32.8	12.5
		NS	NS	NS	5.7	
LSD(0.05)[w]	F × H	6.9	12.2	7.1	5.8	

[z] LSD between kernel harvest maturities at $P = 0.05$.

[y] LSD between fertilizer treatments at $P = 0.05$.

[x] nd = Not detectable.

[w] LSD for the interaction between N-S fertilizer treatments and hybrid at $P = 0.05$.

[NS] Nonsignificant ANOVA.

Differences in kernel and ear characteristics were generally small, with only ear length and kernel depth significantly affected by hybrid. Similar to the results at the IRVSF, ‘Sweetie 82’ produced short ears with deep kernel development. Overall, the potential and kernel yield responses at Urbana were ≈18% higher than that for the same hybrids at the IRVSF, which was probably indicative of the high nutrient status and excellent tilth of the Flanagan silt loam compared to the highly leached sandy soil at the IRVSF.

Kernel DMS. In both years, significant effects due to N-S fertilization influenced the amounts of DMS generated from kernel samples, although the magnitude and relative response in kernel DMS production varied with hybrid and location. At the IRVSF, kernel DMS concentrations in ‘Crisp-N-Sweet 710’ increased 2- to 3-fold at each harvest date as N rate increased from 168 to 310 kg·ha^{-1} (Table 3). A similar response occurred in ‘Sweetie 82’, although not as consistent or as marked as in ‘Crisp-N-Sweet 710’. In both hybrids, there was relatively little effect of S fertilization on kernel DMS content. In ‘FMX 263’, kernel DMS concentrations were highest at the high rate of N (310kg·ha^{-1}) and S (101 kg·ha^{-1}). This response was consistent at each sampling date, suggesting a possible synergistic effect between N and S metabolism on kernel DMS production. However, in three of the hybrids (‘Summer Sweet 7210’, ‘Supersweet Jubilee’, and ‘Sweetie 70’) N-S fertilization had little or no effect on kernel DMS levels.

Similar to the results at the IRVSF, the response in kernel DMS production to N-S fertilization at Urbana varied markedly depending on hybrid (Table 4). In ‘Sweetie 82’, kernel DMS concentrations were generally unaffected by application of either N or S, while in ‘Crisp-N-Sweet 710’, application of 168N increased kernel DMS levels significantly at each sampling date, with little or no effect from S fertilization. Kernel DMS concentrations in ‘FMX 263’ also increased with 168N, however, response to S was mixed; when used in combination with 168N, 101 S had little effect on kernel DMS production, but when used with 0N, 101S decreased kernel DMS levels significantly.

At both locations, kernel DMS concentrations decreased in each hybrid as kernel maturity increased, irrespective of N-S fertilization regime. Averaged over hybrids and fertilizer treatments, the DMS concentration in the kernels at the IRVSF decreased 33% between 20 and 23 DAP and 23% between 23 and 26 DAP, a mean reduction of ≈48% over the 6-day period, or about 8%/day. A similar trend was observed at Urbana, where kernel DMS content decreased ≈78% between 17 and 26 DAP, an average of almost 9%/day.

Kernel MMS and MET. Similar to the response in kernel DMS production, significant interactions between N-S fertilization and

Table 5. Effect of N and S fertilization (F) and hybrid(H) on S-methylmethionine (MMS) and methionine (MET) levels in sweet corn kernels harvested at 23 days after pollination.

Hybrid	N–S fertilizer (kg·ha^{-1})	Kernel MMS (µg·g^{-1})	Kernel MET (µg·g^{-1})
Crisp-N-Sweet 710	168N–0S	75.1 c^{z}	82.8 bc
	168N–101S	75.1 c	94.8 b
	310N–0S	208.6 b	81.3 c
	310N–101S	251.6 a	108.2 a
		**	**
FMX 263	168N–0S	80.8 b	32.1 b
	168N–101S	69.9 c	38.8 b
	310N–0S	66.8 c	28.4 b
	310N–101S	115.7 a	67.9 a
		**	**
Summer Sweet 7210	168N–0S	129.1 b	53.7 b
	168N–101S	155.6 b	65.6 b
	310N–0S	265.1 a	92.5 a
	310N–101S	279.8 a	88.0 a
		**	**
Supersweet Jubilee	168N–0S	68.1	36.6 b
	168N–101S	74.1	38.8 b
	310N–0S	71.7	44.8 a
	310N–101S	84.6	49.2 a
		NS	**
Sweetie 70	168N–0S	146.9	60.4
	168N–101S	162.3	57.4
	310N–0S	122.4	52.2
	310N–101S	156.7	66.4
		NS	NS
Sweetie 82	168N–0S	145.8 b	88.0
	168N–101S	160.5 b	91.0
	310N–0S	233.3 a	98.5
	310N–101S	199.4 a	85.8
		**	NS
LSD(0.05)^{y}	F × H	38.5	14.0

[z] Mean separation within columns by LSD at $P = 0.05$.

[y] LSD for the interaction between fertilizer treatment and hybrid.

NS,*,**Nonsignificant or significant ANOVA at $P = 0.05$ or 0.01, respectively.

Table 6. Dimethyl sulfide (DMS), S-methylmethionine (MMS), and methionine (MET) mole relationships in sweet corn kernels harvested at 23 days after pollination.”

Hybrid	DMS (µmol·g^{-1})	MMS (µmol·g^{-1})	MMS/DMS (µmol·g^{-1})	MET (µmol·g^{-1})	MET/DMS
Crisp-N-Sweet 710	0.96	0.94	0.98	0.62	0.65
FMX 263	0.68	0.51	0.75	0.28	0.41
Summer Sweet 7210	1.03	1.27	1.23	0.50	0.48
Supersweet Jubilee	0.51	0.44	0.86	0.28	0.55
Sweetie 70	0.86	0.90	1.05	0.40	0.46
Sweetie 82	1.14	1.12	0.98	0.61	0.54

[z]Kernel DMS, MMS, and MET levels averaged over N and S fertilizer treatments.

hybrid influenced the levels of MMS and MET generated in kernels at 23 DAP (Table 5). In ‘Crisp-N-Sweet 710’ and ‘FMX 263’, kernel MMS and MET concentrations were highest at the high N and S rates. Kernel MMS and MET levels in ‘Summer Sweet 7210’ also increased at the high N rate, but were not significantly affected by S fertilization. Similarly, increased N fertilization increased kernel MET content in ‘Supersweet Jubilee’ and MMS production in ‘Sweetie 82’, with little or no effect from S. There was no significant effect of N-S fertilizer treatment on either kernel MMS or MET concentrations in ‘Sweetie 70’ or on MET levels in ‘Sweetie 82’. Averaged over hybrids and S rates, kernel MMS and MET concentrations increased 54% and 17%, respectively, as N fertilization increased from 168 to 310 kg·ha^{-1}.

Expressed on a mole basis, the percentage of kernel DMS generated from the complete thermal degradation of MMS at 23 DAP ranged from 75% in ‘FMX 263’ to 123% in ‘Summer Sweet 7210’, with an overall value of ≈96% for the six hybrids (Table 6). The average mole ratio value for kernel MET/DMS was considerably lower at 52%, ranging from 41% in ‘FMX 263’ to 65% in ‘Crisp-N-Sweet 710’. These results support earlier work from this laboratory (Wong et al., 1991) and other researchers (Bills and Keenan, 1968; Williams and Nelson, 1974) and provide further evidence that MMS is a logical precursor of DMS in cooked sweet corn kernels, whereas the specific role of MET in kernel DMS metabolism is not as certain.

Sources of variation in kernel aroma components. The relative contribution of the component sources of variation due to hybrid, N-S fertilization, hybrid × fertilization interaction, and random error on the various chemical components of kernel aroma at 23 DAP is presented in Table 7. The calculations showed that kernel DMS production at the IRVSF was almost equally influenced by the main effects for hybrid and N-S fertilization and by their interaction, while at Urbana, >85% of the variability in kernel DMS was associated with differences due to hybrid, along with lesser (≈12%) but significant variation from fertilizer by hybrid interaction. The calculations also showed that hybrid contributed over 70% of the variation in kernel MMS and MET at the IRVSF in addition to significant variation (≈9%) from hybrid × fertilizer interaction. Kernel moisture content, an industry measure of kernel maturity, was almost equally influenced by hybrid and N-S fertilization at the IRVSF and was primarily affected by hybrid at Urbana.

This replicated study with three of the *sh2* hybrids grown at two locations was conducted to evaluate the effects of N-S fertilization on kernel DMS potential in sweet corn under two distinctly different soil environments. Partitioning the variability in kernel DMS production revealed that the main effects for hybrid were generally the primary source of variation affecting the DMS

Table 7. Percentage of variability explained by the model and by each source of variation in the model for dimethyl sulfide (DMS), S-methylmethionine (MMS), methionine (MET) , and moisture content in kernels harvested at 23 days after pollination at the Illinois River Valley Sand Field and Urbana.[z]

Variable	Model[y]	Hybrid[x]	N–S fertilizer	Hybrid × fertilizer	Error term[w]
		Illinois River Valley Sand Field			
DMS	87.5	34.2	30.8	24.2	10.8
		(<0.0001)	(0.0022)	(<0.0001)	
MMS	96.9	72.4	14.9	8.8	3.9
		(<0.0001)	(0.0017)	(<0.0001)	
MET	96.2	75.4	8.2	9.4	7.0
		(<0.0001)	(0.0562)	(<0.0001)	
Moisture content	67.2	35.7	29.6	16.6	18.1
		(0.0034)	(0.0040)	(0.2698)	
		Urbana			
DMS	97.4	85.1	1.6	11.9	1.4
		(<0.0001)	(0.0522)	(<0.0001)	
Moisture content	83.0	52.8	18.5	8.0	20.7
		(<0.0001)	(0.0867)	(0.2686)	

[z]Values were calculated by dividing the sum of squares of the factor involved by the total sum of squares in the model expressed as percentages; numbers in parenthesis are P values.

[y]Consisted of hybrid, N-S fertilizer, and hybrid × N-S fertilizer interaction.

[x]Composed of three hybrids (‘Crisp-N-Sweet 710’, ‘FMX 263’, and ‘Sweetie 82’).

[w]Composed of replication and replication × fertilizer variability.

potential in sweet corn, although there were significant interactions between hybrid and fertilizer treatments at both locations and main effects of N-S fertilization influencing kernel DMS production at the IRVSF. For the same three hybrids (‘Crisp-N-Sweet 710’, ‘FMX 263’, and ‘Sweetie 82’) used at the two locations, kernel DMS levels at 20 and 23 DAP averaged ≈51% higher at the IRVSF than at Urbana. This difference could possibly be attributed to differences in rates of kernel maturation or soil environments associated with each site. The rapid loss of kernel DMS with increasing kernel maturity was a salient feature at both locations and is of particular concern for the processing sweet corn industry because of its adverse effect on eating quality (Wiley, 1985). Apparently MMS, which is the main precursor of DMS (Williams and Nelson, 1974; this study), is undergoing active conversion to other metabolic products during kernel maturation.

These findings suggest that it may be possible to increase kernel DMS concentrations in *sh2* hybrids by increasing N nutrition to the crop in the field. It is important, however, to distinguish between N fertilization effects on kernel DMS production and kernel yield. The data showed that, at the IRVSF, the increase in kernel DMS content in response to N fertilization (Table 3) was also accompanied by a significant increase in yield (Table 1), suggesting that the influence of N fertilization on kernel DMS may in fact have been due mainly to a crop N deficiency at the lower N rate. This is probably true to some extent, but the relative response in kernel DMS production to N fertilization was considerably greater than the relative increase in kernel yield, indicating that the positive effect of increased N fertilization on DMS concentration was probably independent of the effect on kernel yield. This line of reasoning was also supported by the results at Urbana, where increased N fertilization did not affect yield but increased kernel DMS levels significantly in two of the three hybrids evaluated (Table 4).

The effect of S fertilization on kernel DMS production was generally small and not as clear as that for N fertilization, with only one hybrid (at the IRVSF) showing any positive response to S application, and then in combination with high N rates. In one instance, a high S rate (101 $kg\cdot ha^{-1}$), used in conjunction with ON, decreased kernel DMS levels. Previous reports have shown that plants can obtain S directly from atmospheric sulfur dioxide, which may be absorbed directly through the leaves or dissolved in rainwater and absorbed through the roots (Hoeft et al., 1972; Jones et al., 1979). This source of S may be sufficient to satisfy plant growth demands and kernel DMS requirements.

From a practicalpoint of view, it seems important to use the wide genetic variation in kernel DMS production to develop new varieties with high DMS potentials. These varieties should then receive proper N fertilization to increase kernel DMS concentrations, although ear and kernel yields may not be affected from increased N rates. However, supplemental N fertilization to enhance kernel aromatic quality will require greater attention to fertility and irrigation management to avoid excessive NO,-runoff and contamination of water sources, particularly for sweet corn production on highly leached sandy soils. Based on these results, the application of S to enhance kernel aromatic flavor components, in lieu of plant growth and yield requirements, is not warranted.

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