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Enhanced Emergence and Seedling Vigor in *shrunken-2* Sweet Corn via Seed Disinfection and Solid Matrix Priming

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Abstract. **Presowing seed treatments were devised to improve emergence and crop uniformity of two sweet corn *(Zea mays* L.) cultivars ['Crisp N' Sweet 711' (CNS-711) and 'How Sweet It Is' (HSII)] that carry *shrunken-2 (sh2)* mutant endosperm. The treatments included a fungicide combination, sodium hypochlorite (SH), solid matrix priming (SMP), and SMP combined with SH during treatment (SMPSH). Seed germination was tested in a laboratory cold test. Emergence percentage, emergence rate index (ERI), and seedling dry weight were calculated from field trials. CNS-711, in the cold test and field trials, had a higher germination rate, ERI, final emergence, and seedling dry weight than HSII. In both cultivars, SMPSH significantly improved germination in the cold test and final emergence and ERI in the field trials for HSII compared to nontreated seeds. There was no significant difference between the fungicide and SMPSH treatments regardless of cultivar. These results suggest that the combination of SMP and disinfection with SH can be an alternative seed treatment to fungicides to improve uniformity and stand establishment in *sh2* sweet corns.**

The poor seedling emergence in *sh2* sweet corn cultivars has been attributed to low seed vigor (Styer and Cantliffe, 1983), high susceptibility to seed and soil-borne diseases (Berger and Wolf, 1974), and imbibitional damage (Parera and Cantliffe, 1991). Fungicide seed treatments have been reported to improve stand establishment and uniformity in supersweet corn cultivars (Cantliffe et al., 1975; Parera and Cantliffe, 1990).

Seed priming is used to increase germination rate, improve stand establishment, uniformity, and increase yield (Khan et al., 1980). Seed priming consists of imbibing seeds in an osmotic solution that allows seeds to imbibe water and go through the initial germination stages, but prevents radicle protrusion through the seedcoat (Cantliffe, 1981). Priming treatments have been reported as successful presowing treatments for many species (Bradford, 1986). Priming corn seed has yielded variable results. The emergence rate of corn germinated at low temperatures was improved by priming in a polyethylene glycol (PEG) solution (Bodsworth and Bewley, 1981). Seeds of sugary *(su)* and *sh2* sweet corn genotypes primed with PEG 8000 had lower field emergence than nontreated seeds (Bennett and Waters, 1987). Also, the aeration of the solution, the large volume of solution needed per seed, and the large amount of seeds required for commercial use has restricted osmotic priming for large-seeded species.

SPM is a priming method wherein seeds are moistened for a given time at constant temperature in an organic or inorganic solid matrix carrier to which water has been added (Harman and Taylor, 1988). The SMP uses the osmotic and physical characteristics of the solid carrier to restrict water absorption (Kubik et al., 1989). Early results with SMP on *sh2* sweet corn were not always favorable. Rate of emergence and stand uniformity of *sh2* sweet corn sown in the field were not improved by SMP compared to nonprimed seeds (Cantliffe and Bieniek, 1988). Seedling emergence was enhanced by SMP in 'Jubilee' sweet corn, but was reduced in 'Florida Staysweet' compared to nontreated seeds (Harman et al., 1989).

The objective of this study was to develop a SMP treatment that would consistently improve emergence rate and total emergence of *sh2* sweet corn cultivars under varying field conditions. To effectively prime *sh2* sweet corn, SMP has to control seed-borne pathogens.

Materials and Methods

Plant materials. Seeds of two *sh2* sweet corn cultivars, yellow-kernel CNS-711 and white-kernel HSII (Crookham Seed Co., Caldwell, Idaho), were used in this study.

Seed treatments. Surface disinfection was accomplished by soaking 200 seeds for 15 min in a 0.0596 solution (v/v) of SH. SMP consisted of placing 3 g of seed, 6 g of calcined clay, and 2.5 ml (for HSII) or 2 ml (for CNS-711) of distilled water in a closed container continuously rotated at 5C for 6H, then transferring the sample to 25C and rotating it for 24 h. After 30 h of incubation, 2 ml (HSII) or 1.5 ml (CNS-711) of water (SMP) or SH solution (0.059%) (SMPSH) was added and seeds were incubated an additional 15 h (Parera and Cantliffe, 1991). The fungicide combination seed treatment consisted of soaking 200 g of seed for 2 min in 1 liter of solution of (l-(2-(2,4-dichlorophenyl)-2-(2-propenyloxy)ethyl)-1H imidazole) (imazalil) at 0.653 ml/kg seed, N-[(trichloromethyl)thio]-4-cyclohexene-l ,2-dicarboximide (captan) at 1.958 ml/kg seed, N-(2,6 -dimethylphenyl)-N-(methoxyacetyl) alanine methyl ester (apron) at 0.488 ml/kg seed, and tetramethylthiuram disulfide (thiram) at 3.264 ml/kg seed (Parera and Cantliffe, 1990). After treatment, the seeds were dried back to their initial moisture content (6%) in an incubator at 25 ± 1C and 45% relative humidity (RH). The seeds were stored at 10C and 45% RH before and after treatment.

Cold germination test. Twenty seeds were sown in a plastic box (18.7 x 12.5 x 9 cm) on top of 2.5 cm of soil (Arredondo fine sand, loamy, silaceous, hyperthermic Grossarenic Palen-

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Abbreviations: CNS-711, 'Crisp N' Sweet 711'; ERI, emergence rate index; HSII, 'How Sweet It Is'; SH, sodium hypochlorite; SMP, solid matrix priming.

Table 1. Effect of seed treatments on germination of two *sh2* sweet corn cultivars in a cold germination test.

	Cultivar	
	HSII	CNS-711
Seed treatment	Germination (%)	Germination (%)
SMPSH	33	46
SMP	2	13
SH	0	2
Fungicide (F)	20	57
Control (C)	4	31
Orthogonal contrast		
SMPSH vs. C	**	*
SMP vs. SH	NS	**
SMPSH vs. SMP	**	**
SMPSH vs. F	NS	NS

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

Table 2. Effect of seed treatments on ERI, emergence percentage, and dry weight (DW) of HSII sweet corn cultivars in a field experiment planted in 26 Oct. 1989 at Gainesville, Fla.

	HSII		
Seed treatment	ERI	Emergence (%)	DW[z] (mg)
SMPSH	76	63	71
SMP	70	50	69
SH	30	27	55
Fungicide (F)	79	74	73
Control (C)	38	44	32
Orthogonal contrast			
SMPSH vs. C	**	**	*
SMP vs. SH	**	**	NS
SMPSH vs. SMP	NS	NS	NS
SMPSH vs. F	NS	NS	NS

[z]Values are means of 20 plants 19 days after sowing.
NS,*, ** Nonsignificant or significant at $P = 0.05$ or 0.01, respectively.

undult) taken from a field where corn was grown continuously for 2 years. The soil was compacted and another *2.5* cm of soil was placed on top of the seeds. The soil was adjusted to 70'% of its water-holding capacity. The containers were sealed and incubated at 10C for 7 days, then transferred to 25C for 4 days. Total germination percentage was calculated. Seedlings with leaves 2 mm in length above the soil were considered germinated.

Field studies. Field plots were established on 26 Ott. 1989 and *7* Mar., 27 Apr., and 8 Nov. 1990 at the Inst. of Food and Agricultural Sciences, Horticultural Unit, Gainesville, Fla., on an Arredondo fine sand soil. The plots were 7.60 m long on beds 1.22 m apart, with each bed 0.70 m wide and 0.20 m in height. Two seeds were sown 4 cm deep, every 30 cm in each plot (50 seeds/plot). Overhead sprinkler irrigation was applied as needed. ERI (Shmueli and Goldberg, 1971) and percent emergence were calculated. Five seedlings were cut at the soil level 22 days after sowing (DAS), weighed, and then dried at 75C for 72 h and reweighed. In the March and April sowings, the central 6 m of each plot were harvested. The ears were classified according to U.S. Dept. of Agriculture (1954) quality standards, then counted and weighed. Daily maximum and minimum soil temperatures at the 5-cm depth were recorded for each planting.

Statistical analyses. The experiments were conducted as a randomized complete-block design, with treatments replicated four times. Percent emergence data were analyzed after square root arcsin transformations. Main effects of treatments were partitioned into orthogonal contrasts.

Results and Discussion

Since the interactions of treatment × cultivar and treatment × sowing date were significant, main effects were partitioned and analyzed for each cultivar and sowing time. Only 4% of the nontreated HSII and 31% of CNS-711 seeds germinated in a cold test experiment (Table 1). The SMPSH treatment significantly improved germination in both cultivars compared to nontreated seeds. In both cultivars, the germination of seed treated with fungicide did not significantly differ from that of SMPSH-treated seeds.

The cultivar CNS-711 had earlier seedling emergence (higher ERI) and higher emergence percentage and seedling vigor than HSII in the field test in Fall 1989 (Table 2). The seed treatments did not significantly improve the emergence percentage (range 81% to 94%) or seedling vigor (ranges: ERI, 105-122; dry

Table 3. Effect of seed treatments on ERI, emergence percentage, and dry weight (DW) of two *sh2* sweet corn cultivars in a field experiment planted 7 Mar. 1990 at Gainesville, Fla.

	Cultivar					
	HSII			CNS-711		
Seed treatment	ERI	Emergence (%)	DW[z] (μg)	ERI	Emergence (%)	DW (mg)
SMPSH	217	66	2240	370	98	1117
SMP	100	34	645	343	93	1110
SH	118	42	715	364	93	1475
Fungicide (F)	275	80	1125	386	95	1115
Control (C)	124	42	955	323	91	1136
Orthogonal contrast						
SMPSH vs. C	**	**	NS	**	NS	NS
SMP vs. SH	NS	NS	NS	NS	NS	NS
SMPSH vs. SMP	**	**	NS	NS	NS	NS
SMPSH vs. F	NS	NS	NS	NS	NS	NS

[z]Values are means of 20 plants 27 days after sowing.
NS, *, **Nonsignificant or significant at $P = 0.05$ or 0.01, respectively.

Table 4. Effect of seed treatments on ERI, emergence percentage, and dry weight (DW) of two *sh2* sweet corn cultivars in a field experiment planted 23 Apr. 1990 at Gainesville, Fla.

	Cultivar					
	HSII			CNS-711		
Seed treatment	ERI	Emergence (%)	DW[z] (mg)	ERI	Emergence (%)	DW (mg)
SMPSH	145	50	1327	230	83	2403
SMP	98	32	1550	208	79	2480
SH	76	32	1300	187	72	2073
Fungicide (F)	132	58	668	192	79	2120
Control (C)	56	22	393	160	66	1901
	Orthogonal contrast					
SMPSH vs. C	**	**	**	**	NS	NS
SMP vs. SH	NS	NS	NS	NS	NS	NS
SMPSH vs. SMP	*	NS	NS	NS	NS	NS
SMPSH vs. F	NS	NS	NS	NS	NS	NS

[z]Values are means of 20 plants 27 days after sowing.
[NS], *, **Nonsignificant or significant at $P = 0.05$ or 0.01, respectively.

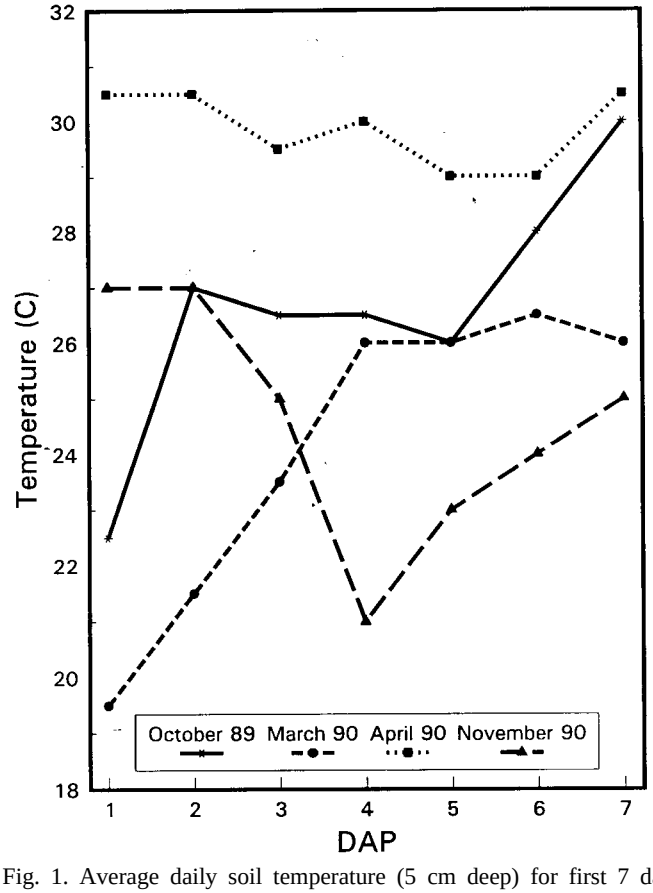

Fig. 1. Average daily soil temperature (5 cm deep) for first 7 days after planting (DAP) in Fall 1989, Spring 1990, and Fall 1990 field experiments.

weight, 135–175 g) of CNS-711. In HSII, SMPSH treatment significantly improved emergence percentage, ERI, and dry weight of the seedlings compared to nontreated seeds (Table 2). The SMPSH and fungicide treatments produced the highest and fastest emergence and were not significantly different from each other.

Similar to Fall 1989 trials, CNS-711 had more rapid emergence and higher emergence and seedling vigor than HSII in both Spring 1990 sowings (Tables 3 and 4). The SMPSH treatment significantly improved the emergence rate compared to nontreated seeds in both cultivars at both plantings (March and April). The SMPSH and fungicide treatments both increased final emergence and ERI of HSII compared to the other treatments. Under more stressful conditions (higher soil temperature) in April (Fig. 1), the SMPSH treatment also significantly enhanced HSII seedling dry weight over the control and the rate of emergence compared to SNIP treatment alone (Table 4). There were significant differences in yield among treatments in Mar. and Apr. 1990 trials (data not shown), where the final marketable yields were directly related to the final stand. Under cooler conditions of Nov. 1990 (Fig. 1), HSII seeds treated by SMPSH emerged more rapidly and had significantly higher final emergence and dry weight compared to the other treated and nontreated seeds (Table 5). Significantly higher ERI was also shown in CNS-711 seeds primed via SMPSH.

The SMP presowing treatment provides ideal conditions to deliver other products, such as biocontrol agents, to the seed (Harman and Taylor, 1988). SH has been used successfully as a seed disinfectant in *su* sweet corn to control *Fusarium moniliforme* (Anderegg and Guthrie, 1981). The SH and SMP treatments alone were not effective in cold test and field experiments. The addition of SH to the SMP treatment significantly enhanced seed germination and emergence compared to seeds only disinfected with SH or primed alone. Our results indicated that SMP is an excellent delivery system to include SH as a seed disinfectant.

Greater differences in seed and seedling performance between the nontreated seeds and primed seeds via SMPSH were measured under high (April sowing) or low soil temperature (cold test and Fall 1990). Rapid imbibition, increased seed leakage, and pathogen growth and development may contribute to rapid deterioration of the seeds under these stressful conditions. Lower imbibitional rate and seed leakage had been observed in primed than in control sweet corn seeds (Parera and Cantliffe, 1991). The disinfectant treatment of SH added after partial seed hydration in the SMP process may have contributed to a more effective control of seed-borne pathogen growth and development. The fungicide combination treatment was also effective in increasing germination in the laboratory and field stand in supersweet corn (Cantliffe and Bieniek, 1988; Parera and Cant-

Table 5. Effect of seed treatments on ERI, emergence percentage, and dry weight (DW) of two *sh2* sweet corn cultivars in a field experiment planted 8 Nov. 1990 at Gainesville, Fla.

	Cultivar					
	HSII			CNS-711		
Seed treatment	ERI	Emergence (%)	DW[z] (mg)	ERI	Emergence (%)	DW (mg)
SMPSH	167	84	85	178	85	83
SMP	67	45	24	167	79	87
SH	25	19	25	160	82	65
Fungicide (F)	116	76	42	179	89	86
Control (C)	26	19	16	136	81	57
	Orthogonal contrast					
SMPSH vs. C	**	**	**	**	NS	NS
SMP vs. SH	**	**	NS	NS	NS	NS
SMPSH vs. SMP	**	**	**	NS	NS	NS
SMPSH vs. F	**	*	**	NS	NS	NS

[z]Values are means of 20 plants 22 days after sowing.
[NS],*,**Nonsignificant or significant at $P = 0.0.5$ or 0.01, respectively.

liffe, 1990). However, it was necessary to combine four fungicides to achieve the same germination rate and field emergence reached with the SMPSH treatment.

From the laboratory and field results presented, SMPSH improved seed germination, emergence rate, final field stand, and seedling vigor in CNS-711 and HSII *sh2* sweet corn cultivars compared with nontreated seeds, especially when *sh2* cultivars have inherently poor seed quality and under stressful conditions. The treatment may be a practical replacement for fungicide seed treatments on *sh2* sweet corn cultivars. The response of this treatment to a large range of environmental conditions and cultivars needs to be investigated.

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