

Seed Priming Promotes Germination and Seedling Development of Hybrid and Open Pollinated Cultivars of Super Sweet Corn

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ABSTRACT: Super sweet corn production is faced with problems of stand establishment resulting from low seedling vigor due to inadequate starch accumulation in its seed endosperm. Seed priming has been used to enhance seed germination. This study aimed to evaluate the effects of hydropriming (distilled water, H₂O), 300-fold diluted wood vinegar and halopriming 0.1 M sodium chloride and 0.1 M calcium chloride on germination, seedling growth and yield of ‘Hibrix53’ (F1-hybrid) and ‘ATS-5’ (open pollinated) cultivars of super sweet corn. Fresh and artificially accelerated aged seeds were used in the laboratory study. The primed seeds germinated faster than unprimed fresh and aged hybrid and open pollinated seeds. Wood vinegar primed seeds had a significantly higher percentage germination than the other treatments in fresh hybrid seeds. However, negative priming effects were noted during final evaluation at the end of germination tests. Under field conditions using fresh seeds, primed seeds of both cultivars had better field emergence than unprimed seeds, with the wood vinegar priming treatment being the best among the treatments for fresh hybrid seeds. Seed priming treatment did not alter any of the agronomic traits, including yield and yield components. **Keywords:** *Zea mays* L. var. *saccharata*, seed hydration, seed treatments, plant derived smoke, field establishment

Introduction

Super sweet corn, *Zea mays* L. var. *saccharata* is a variety of maize with high sugar content, which is mainly cultivated for human consumption. It mutated from field corn as a result of a naturally recessive mutation in the *shrunken-2* (*sh₂*) genes controlling the conversion of sugar to starch in the corn kernel (Erwin, 1951). This gene results in the absence of substantial

starch accumulation in the kernel (Fan et al., 1998), which affects seedling vigor and causes problems in stand establishment for sweet corn cultivars (Cantliffe et al., 1975). Sweet corn hybrid cultivars are generally high yielding, have high germinability, increased seedling vigor and are disease resistant; however, some farmers still prefer open pollinated cultivars since the seed is cheaper and readily available, and because the seed can be saved from previous season's

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crops. However, when the seed is carried over from one season to the next, it is often stored under poor conditions, resulting in poor germination and weak plants that cannot compete well with weed competition (Levey, 2003). Seed treatments have been used to improve seedling vigor, seedling uniformity and increase yields of different crops (Adebisi et al., 2011; Bhardwaj et al., 2012). Seed priming is a process in which the seeds are pre-sowed in water or osmotic solution, which allows the seeds to imbibe, but not long enough to allow radicle emergence (Bradford and Bewley, 2002). Seed priming can be achieved through hydropriming (soaking in water), osmopriming (soaking in osmotic solutions such as polyethylene glycol (PEG)), halopriming (soaking seeds in salt solution), solid matrix priming (mixing seeds in a mixture of water and insoluble matrix particles) and by the use of plant growth regulators (Harris et al., 1999; Capron et al., 2000; Chiu, 2002). Different chemicals, plant hormones and plant derived smoke, have been used successfully as priming agents. However, their effectiveness varies under different conditions as well as among different crop species. Sivritepe et al. (2003) reported increased emergence and dry weight of melon plants priming under saline conditions using NaCl. Hydropriming and osmopriming techniques have been reported to improve the germination of sweet corn seeds (Patera and Cantliffe, 1991; Sung and Chiu, 2001). In contrast, lower field emergence than for non-treated seeds has been reported in *sugary* and *sh₂*-sweet corn genotypes primed with PEG 8000 (Bennett and Waters, 1987). The rate of emergence and stand uniformity of *sh₂*-sweet corn sown in the field was not improved by solid matrix priming (Cantliffe and Bieniek,

1988). Wood vinegar or pyroligneous acid, another form of plant derived smoke has many uses in plant development. Wood vinegar used as foliar fertilizer enhanced yields of cucumber, lettuce, cole (Jun et al., 2006) and Jasmine rice (Jothityangkoon et al., 2007). Mixing charcoal and wood vinegar in planting materials improved growth, branching and survival rate of zinnia (Kadota and Niimi, 2004) and increases yield of Hiratake mushroom (*Pleurotus ostreatus*) (Yoshimura et al., 1995). Wood vinegar was reported to promote seed germination and seedling development in various plants, including rice when utilized as priming agents (Kulkarni et al., 2006; Jothityangkoon et al., 2007).

Although many laboratory studies have proved seed priming to be effective treatment for seed invigoration in different crops, with super sweet corn, little research has been reported on the effects of the use of wood vinegar as a priming agent for sweet corn, in relation to the priming effects on different aspects of seed quality, and the consequent effects on final crop yield. Therefore, this research was carried out under laboratory and field conditions to investigate the effects of different seed priming methods, on germination, seedling development and yield of hybrid and open pollinated cultivars of super sweet corn in attempt to improve seed quality and subsequent stand establishment.

Materials and methods

Plant materials

Two types of super sweet corn with different genetic backups, hybrid and open pollinated (OP), were used in this study. The commercial F₁-Hybrid ('Hibrix53') cultivar which was not treated with chemicals to avoid interference with

the priming treatments was provided by the Pacific Seed Company in Thailand, while open pollinated (OP), an F_3 population of 'ATS-5' derived from its F_1 , was obtained from the Plant Breeding Research Center for Sustainable Agriculture, Faculty of Agriculture, Khon Kean University. Two types of seeds based on two quality attributes, namely freshly harvested (good quality) and artificially accelerated (AA) aged (deteriorated quality) were used. To achieve seeds of deteriorated quality, hybrid and OP seeds were artificially aged by placing the seed in small copper wire baskets which were put in an aging chamber set at 42°C and 100% relative humidity for 96 h, as described by Delouche and Baskin (1973).

Priming treatments

Seeds of both qualities and corn types were soaked in distilled water (H_2O), $CaCl_2$ (0.1 M), NaCl (0.1 M) solution and 300-fold diluted wood vinegar (WV) solution (wood vinegar: water, 1: 300 v/v) for 12 h in glass cups covered with aluminum foil paper in an incubator adjusted at 25°C under dark conditions. Wood vinegar made from eucalyptus wood and purchased from Energy Ashram, Appropriate Technology Association, Thailand. The chemical composition of the wood vinegar has been reported by Mungkunkamchao et al. (2013).

Laboratory experiment

Fresh and AA aged hybrid and OP seeds were primed, as described. After priming, the seed samples were drained and tested for germination. Treatments were arranged in a 2x5 factorial based on a completely randomized design (CRD), replicated four times, in the Seed Technology Laboratory, Faculty of Agriculture,

Khon Kaen, Thailand. The four replicates of 50 seeds of each treatment were germinated between moistened double layered rolled germination papers. Rolled paper containing the seeds was placed into covered plastic containers to avoid moisture loss. Seeds were allowed to germinate over a period of 7 days in the germination chamber at 25°C for 12 h under light. First and final counts of the germination were done on the 4th and 7th days in accordance with International Seed Testing Association (ISTA, 2007). Seedlings whose radicle and shoots reached 1 cm and 3 cm long, respectively, were considered normally germinated, while those with short, thick and spiral shoots and stunted primary root were considered as having germinated abnormally (ISTA, 2003). First and final germination percentages were calculated in reference to normal seedlings and were based on equation of Ashraf and Foolad (2005) as; $GP = (\text{total germinated seeds}) / (\text{total number of seeds})$.

At the end of the germination test (7 days), the roots and shoots were removed from the seed, their length measured and then oven-dried at 80°C for 24 h or until constant dry weight was achieved. The dried roots and shoots were weighed and their mean dry weights and consequently mean seedling dry weights were determined.

Field experiment

Good quality and OP treated seed were used. After priming, the seed samples were drained and sown in the field on individual plots 16 m² in area, with 4 rows 5.0 m long, using a row spacing of 0.80 m. The treatments were arranged in a 2x5 factorial based on randomized complete block design (RCBD) with three

replications. The experiment was conducted at the Vegetable Research Farm, Faculty of Agriculture, Khon Kaen, Thailand, during the 2015 rainy season (July to October). The experimental fields were prepared using a mould-board plough, with seedbed preparation done using a tandem disk. Seeds were planted at a rate of 3 seeds per hole and later thinned to 1 plant, 7 days after sowing (DAS). Field operations, which included cultural practices, weed control and fertilization rates, used were in accordance with Thailand agricultural recommendations. Fertilizer 15N-15P-15K was applied at the rate 312.5 kg·ha⁻¹ before planting, while at four weeks after planting fertilizers 15N-15P-15K plus 46N-0P-0K were applied at a rate of 156.3 kg·ha⁻¹. Weeding was done manually. No pesticides were applied and the crop benefitted from continuous and heavy rainfall during the season (there was no need for supplementary irrigation).

The data on days-to-silking, and days-to-tasseling were recorded at the pollination stage, when 50% of all plants in each plot had produced silk and tassels, respectively. Seedling height was measured for 10 randomly chosen plants in each plot at 15 DAS. Shoot-dry-weight (SDW) was also recorded at 15 DAS by cutting 10 plants at soil surface level in each experimental plot, with the samples then being oven dried at 80°C for 96 h. Agronomic traits; seedling emergence percentage, ear and plant height, fresh yield and yield components (i.e. number of fresh ears, un-husked and husked yield, number of seed rows, number of seeds in a row, ear diameter, ear length, tip length and kernel weight) were collected.

Statistical analysis

Analysis of variance (ANOVA) was performed on the data for each of the parameters. Data were expressed as means and then compared by the least significant difference (LSD) at $P \leq 0.05$ (Gomez and Gomez, 1984). The data in percentages were transformed into arcsine square root before analysis and back transformed data is presented.

Results and Discussion

Effects of seed priming methods on the germination of hybrid and OP super sweet corn seeds

Priming has been reported to improve germination and seedling establishment in many crops (Harris et al., 2001). In this study, seedling vigor (determined by first count germination percent) of both good (fresh) and deteriorated (AA aged) quality seeds was significantly improved by all the priming treatments in both cultivars, in both laboratory and field experiments (Table 1, 2 and 3). Seed priming with WV in fresh hybrid cultivars significantly increased germination vigor from 12.5% in control (dry seed) to 59.5% and from 27% to 48% in the laboratory experiments (Table 1 and 2). The results from the field experiment validated this finding, with field emergence of fresh hybrid wood vinegar primed seeds being faster than for other priming treatments and the control (Table 3). The hormonal effect of butenolide 3-methyl-2H-furo[2,3-c]pyran-2-one found in smoke or wood vinegar might have induced the more rapid seed germination in hybrid seed, which is consistent with the observations reported by Flematti et al. (2004). Furthermore, this result is also in line with previous findings

which reported that wood vinegar significantly improved seed germination and field emergence of all different seed deteriorated levels of rice seed soaked in wood vinegar at 300 times dilution level (Jothityangkoon et al., 2007). The germination of the two types of corn was affected differently in the two experimental conditions. In the laboratory set up, vigor of seedlings (based on first count at 4 days after sowing) was higher in OP seeds at 47.7% and 61.1%, compared to hybrid seeds at 38.3% and 40.9% for fresh and AA aged seeds, respectively (Table 1 and 2). This effect can probably be attributed to the smaller OP seed size which requires less water to be absorbed for germination; 100 seeds of hybrid and OP weighed 17.95 g and 12.36 g, respectively. This is in agreement with findings previously reported by Sadeghi et al. (2011), that large seeds take more time to germinate resulting in a slower speed of germination. In the field set up, where hybrid seeds established faster with (36.9%) germination after 7 days compared to OP seeds (32.2%), but by 14 days, OP germination was statistically similar to hybrid (Table 3). The heavy and continuous rainfall in the field situation favored water uptake of the hybrid cultivar whose genetic makeup played a vital role for hybrids which have been bred for fast and high germination as well as seedling vigor. The priming treatments did not significantly alter the final germination percentages of fresh and AA aged seeds of both corn types in both the laboratory and field experiments. Reduced germination with priming were observed in final germination percentages amongst priming treatments, apart from the CaCl_2 treatment of fresh and aged seeds in the laboratory experiment (Table 1 and 2). This probably

reflected the fact that, unlike PEG, Ca^{+} and Cl^{-} penetrate the cell membranes and influence the cellular mechanisms, independent of osmotic stress (Chen and Arora, 2013). Previous findings on pepper (Amjad et al., 2007) and sugarcane (Patade et al., 2009) showed similar results, with the soaking of seeds in salt solutions improving seed germination, seedling emergence and growth. In related findings, (Kaya et al., 2006; Moosavi et al., 2009) observed that osmotic stress rather than salt toxicity prevented seed germination of NaCl primed seeds of sunflower and amaranth. In this study, when compared between two salt solutions, CaCl_2 was more effective than NaCl. Salt toxicity caused by NaCl may have occurred and this needs further investigation.

Effects of different priming methods on seedling development of fresh and AA aged hybrid, and OP super sweet corn seeds

Rapid seedling establishment and growth is essential to minimize crop risks due to environmental conditions or insect and disease problems during field emergence, which is another advantage of the use of primed seed (Passam et al., 1989). In this study, the priming treatments had significant beneficial effects on shoot and root biomass. This was mainly due to the accelerated metabolism occurring in primed seeds that advanced seedling development when compared with unprimed fresh seed, in both laboratory and field conditions. However, in aged seed, the shoot biomass was improved to the level of dried seed, which was greater than for aged dry seed (Table 2). A higher root biomass of 0.030 g was obtained in both fresh and AA aged seed, compared with 0.019 g in fresh and 0.022 g in AA aged OP seed

(Tables 1 and 2). The higher seedling growth can probably be attributed to the genetic makeup of the hybrid seed which resulted in higher vigor bigger seed size and more carbohydrates and other nutrients required for seedling development when compared with the smaller sized OP seed. This observation is consistent with findings reported by Singh et al. (1972) who reported that large soya bean seeds had a greater supply of stored energy to support early seedling growth. A similar result was also reported by Guan et al. (2014) for sorghum seed. In a related study, Farooq et al. (2011) reported that pre-soaking with inorganic salts

improved seedling emergence, shoot and root length, and biomass. Additionally, Kaur et al. (2002) reported three to four times more growth in root and shoot length of seedlings obtained from hydro primed seeds relative to seedlings obtained from non-primed seed in drought conditions. In contrast to these findings, in the present study no significant differences were observed for root lengths and root dry weights of primed hybrid and OP super sweet corn seeds (Tables 1 and 2). This could be attributed to the roots being blocked and restricted when germinated on rolled papers in the laboratory experiments.

Table 1 Germination percentage, shoot and root length, shoot and root dry weight of fresh 'Hibrix53' and 'ATS-5' super sweet corns, unprimed and primed with distilled water, 300-fold diluted wood vinegar (WV), 0.1 M NaCl and 0.1 M CaCl₂ solution at 25 °C for 12 h in laboratory

Parameters	Treatment	Germination (%)		Shoot development		Root development	
		First count	Final count	Shoot length (cm)	Shoot dry wt (g)	Root length (cm)	Root dry wt (g)
Corn type (V)	Hybrid	38.3 ^{bv}	87.2 ^a	12.4 ^b	0.030 ^b	19.2 ^a	0.030 ^a
	OP	47.7 ^a	73.3 ^b	15.0 ^a	0.034 ^a	16.0 ^b	0.019 ^b
F-test		**	**	**	**	**	**
Priming (P)	Dry	19.8 ^b	85.0 ^a	10.0 ^b	0.026 ^c	16.7 ^b	0.026
	H ₂ O	48.5 ^a	76.5 ^b	14.9 ^a	0.036 ^a	16.7 ^b	0.023
	WV ^x (1:300 v/v)	53.8 ^a	76.8 ^b	14.9 ^a	0.033 ^{ab}	16.6 ^b	0.022
	NaCl (0.1 M)	44.0 ^a	75.0 ^b	14.7 ^a	0.034 ^{ab}	19.6 ^a	0.027
	CaCl ₂ (0.1 M)	49.0 ^a	88.0 ^a	14.2 ^a	0.031 ^b	18.5 ^a	0.024
F-test		**	**	**	**	**	ns
Interaction (V×P)	Hybrid×Dry	12.5 ^d	91.0 ^a	8.6	0.022	18.8	0.033
	Hybrid ×H ₂ O	42.0 ^{bc}	83.5 ^{ab}	14.0	0.035	17.7	0.026
	Hybrid ×WV	59.5 ^a	88.5 ^{ab}	14.1	0.033	18.9	0.029
	Hybrid×NaCl	39.5 ^{bc}	82.5 ^{ab}	12.1	0.030	20.5	0.032
	Hybrid×CaCl ₂	38.0 ^{bc}	90.5 ^{ab}	12.6	0.031	19.9	0.031
	OP×Dry	27.0 ^{cd}	79.0 ^{bc}	11.3	0.030	14.6	0.019
	OP×H ₂ O	55.0 ^{ab}	69.5 ^c	15.9	0.038	15.7	0.020
	OP×WV	48.0 ^{ab}	65.0 ^d	15.7	0.034	14.3	0.016
	OP×NaCl	48.5 ^{ab}	67.5 ^{cd}	16.5	0.038	18.7	0.022
OP×CaCl ₂	60.0 ^a	85.5 ^{ab}	15.8	0.030	17.0	0.017	
F-test		**	*	ns	ns	ns	ns
CV (%)		16.45	5.94	9.31	12.07	8.85	17.25

'Hibrix53' F₁ cultivar, ATS-5' OP cultivar

First and final count of the germination were done on the 4th and 7th days.

NS, *, ** = non-significant, significant different at P ≤ 0.01 and P ≤ 0.05, respectively

Means in same column with different letters are significantly different at P < 0.05 by LSD

Table 2 Germination percentage, shoot and root length, shoot and root dry weight of AA aged 'Hibrix53' and 'ATS-5' sweet corns, unprimed and primed with distilled water, 300-fold diluted wood vinegar (WV), 0.1 M NaCl and 0.1 M CaCl₂ solution at 25 °C for 12 h in laboratory

Parameters	Treatments	Germination (%)		Shoot development		Root development	
		First count	Final count	Shoot length (cm)	Shoot dry wt (g)	Root length (cm)	Root dry wt (g)
Corn type (V)	Hybrid	40.9 ^b	85.9 ^a	11.6 ^b	0.029 ^b	19.0 ^a	0.033 ^a
	OP ^y	61.1 ^a	80.8 ^b	14.2 ^a	0.034 ^a	17.3 ^b	0.022 ^b
F-test		**	**	**	**	*	*
Priming (P)	Dry	38.8 ^b	85.3 ^{ab-c}	12.9 ^b	0.034 ^a	18.0	0.026
	Dry aged	38.0 ^b	86.3 ^{ab}	9.9 ^c	0.025 ^b	16.2	0.025
	H ₂ O	57.8 ^a	79.8 ^c	14.1 ^{ab}	0.034 ^a	18.7	0.028
	WV ^x (1:300 v/v)	59.8 ^a	81.3 ^{bc}	14.5 ^a	0.033 ^a	18.3	0.026
	NaCl (0.1 M)	57.8 ^a	80.5 ^c	12.9 ^b	0.031 ^a	19.0	0.030
	CaCl ₂ (0.1 M)	54.0 ^a	87.3 ^a	13.3 ^{ab}	0.032 ^a	18.7	0.028
F-test		**	**	**	**	ns	ns
Interaction (V×P)	Hybrid×Dry	26.5 ^e	95.0 ^a	11.9	0.031	18.1	0.030
	Hybrid×Dry aged	27.0 ^e	85.5 ^{b-d}	9.0	0.025	17.0	0.029
	Hybrid×H ₂ O	47.0 ^{cd}	79.5 ^{c-e}	12.4	0.032	19.9	0.035
	Hybrid×WV	48.0 ^{cd}	81.0 ^{c-e}	12.8	0.031	19.6	0.031
	Hybrid×NaCl	54.5 ^{bc}	84.0 ^{b-d}	11.6	0.031	19.4	0.037
	Hybrid×CaCl ₂	41.5 ^d	90.5 ^{ab}	11.9	0.029	19.3	0.034
	OP×Dry	51.0 ^{b-d}	75.5 ^e	14.3	0.038	17.4	0.023
	OP×Dry aged	48.0 ^{cd}	87.0 ^{bc}	10.9	0.026	15.5	0.022
	OP×H ₂ O	68.5 ^a	80.0 ^{c-e}	15.8	0.037	17.5	0.022
	OP×WV	71.5 ^a	81.5 ^{c-e}	16.2	0.036	17.0	0.021
	OP×NaCl	61.0 ^{ab}	77.0 ^{d-e}	14.1	0.032	18.6	0.023
	OP×CaCl ₂	66.5 ^a	84.0 ^{b-d}	14.7	0.034	18.2	0.022
F-test		*	*	ns	ns	ns	ns
CV (%)		15.86	6.74	9.63	10.37	10.87	13.12

'Hibrix53' F₁ cultivar, 'ATS-5' OP cultivar

First and final count of the germination were done on the 4th and 7th days.

ns, *, ** = non-significant, significant different at P ≤ 0.01 and P ≤ 0.05, respectively

Means in same column with different letters are significantly different at P ≤ 0.05 by LS

Effects of different priming treatments on selected growth parameters, yield and yield components, of hybrid and OP super sweet corn

Fresh vegetative yield is a complex character that results from the interactions of many yield contributing characters. In this study, the priming treatments did not significantly affect the plant and ear heights (Table 3). Furthermore, the priming treatments did not significantly affect the yield or yield components of both the hybrid and OP seed; however, the hybrid corn type was consistently superior to OP for all the parameters

(Table 4). This suggests that the beneficial effect of seed priming recorded at the seedling stage were lost as the crop approached maturity. As a result, yield and yield components were not significantly better for plants based on the use of primed seed (Table 4). Limited studies have so far reported that seed priming can potentially increase grain yield. Harris et al. (1999) reported that hydro-priming did not only improved seedling establishment and early seedling vigor of upland rice, maize and chickpeas, resulting in faster development, with earlier flowering and

maturity, and also higher yields. However, in the current study, there was no significant difference in fresh vegetative yield among priming treatments in both corn cultivars. In a related study, Subedi and Ma (2005) reported that seed primed with water, osmotic solution (2.5% KCl), and plant growth regulators did not improve grain yield of corn grown under temperate and humid conditions. Similarly, Giri and Schillinger (2003) noted no significance in yield of the deep-planted winter wheat seed primed with water, KCl and polyethylene glycol. Furthermore, Murungu et al. (2004) reported little or no effect of seed priming in corn yield when tested in a semi-arid area of Zimbabwe. These results suggest that the

growing environment can potentially have an important role in determining the final yield, and that the potential positive effects of seed priming is determined by the complex interaction of several factors (Patera and Cantliffe, 1991). In addition, the use of high quality seed, favorable rainfall and the cultural practices (thinning to one plant per planting station) in this study, collectively provided favorable conditions for the plants. However, in conditions where the broadcasting method of planting is adopted, the use of poor quality seed and the poor growing environment might result in the benefits of seed priming being observed in plant growth and final crop yield.

Table 3 Germination percentage, shoot length, shoot dry weight, plant and ear height of 'Hibrix53' and 'ATS-5' super sweet corns, unprimed and primed with distilled water, 300-fold diluted wood vinegar (WV), 0.1 M NaCl and 0.1 M CaCl₂ solution at 25 °C for 12 h grown under field conditions

Parameter	Treatments	Germination (%)		Shoot development		Plant height (cm)		Ear height (cm)
		First count	Final count	Shoot length (cm)	Shoot dry wt (g)	30 DAS	45 DAS	
Corn type (V)	Hybrid	36.9 ^a	79.9	49.6 a	1.591 a	165.6 ^a	218.7 ^a	97.8 ^a
	OP ^y	32.2 ^b	77.8	46.0 b	1.397 b	139.6 ^b	177.3 ^b	53.2 ^b
F-test		**	ns	**	*	**	**	**
Priming (P)	Dry	25.8 ^b	78.5	48.5	1.233 b	153.4	202.2	78.7
	H ₂ O	38.9 ^a	84.0	49.6	1.680 a	154.3	193.2	73.8
	WV (1:300 v/v)	35.4 ^a	75.3	44.9	1.340 b	150.4	194.2	74.8
	NaCl (0.1 M)	36.9 ^a	77.1	47.7	1.582 a	150.0	200.0	71.6
	CaCl ₂ (0.1 M)	35.9 ^a	79.4	48.1	1.635 a	155.1	200.4	78.6
F-test		**	ns	ns	**	ns	ns	ns
Interaction (V×P)	Hybrid×Dry	23.9 ^f	91.0	8.6	1.268	160.3	217.6	95.6
	Hybrid×H ₂ O	47.8 ^b	83.6	14.0	1.658	167.0	215.0	96.5
	Hybrid×WV	58.4 ^a	80.4	14.1	1.635	164.2	213.6	96.8
	Hybrid×NaCl	37.4 ^{bc}	78.4	12.8	1.649	167.1	223.6	99.1
	Hybrid×CaCl ₂	37.1 ^{bc}	76.3	12.6	1.745	169.5	223.6	101.0
	OP×Dry	28.0 ^{ef}	82.2	11.3	1.197	146.5	186.7	61.7
	OP×H ₂ O	30.1 ^{de}	84.4	15.9	1.703	141.5	171.3	51.1
	OP×WV	32.3 ^{c-e}	70.2	15.7	1.046	136.6	175.0	52.8
	OP×NaCl	36.4 ^{bc}	75.8	16.5	1.516	132.9	176.3	44.0
OP×CaCl ₂	34.8 ^{b-d}	76.3	15.8	1.525	140.6	177.3	56.1	
F-test		**	ns	ns	ns	ns	ns	ns
CV (%)		5.63	8.34	5.36	12.41	6.00	6.64	9.03

'Hibrix53' F₁ cultivar, ATS-5'OP cultivar, DAS = days after sowing

First and final count of the germination were done on the 4th and 7th days.

NS, *, ** = non-significant, significant different at P ≤ 0.01 and P ≤ 0.05, respectively

Means in same column with different letters are significantly different at P ≤ 0.05 by LSD

Table 4 Effect of priming methods on yield and yield components of fresh 'Hibrix53' and 'ATS-5' super sweet corn cultivars unprimed and primed with distilled water, 300-fold diluted wood vinegar (WV), 0.1 M NaCl and 0.1 M CaCl₂ solution at 25 °C for 12 h grown under field conditions

Yield and yield parameters	Dry		H ₂ O		WV (1:300 v/v)		NaCl (0.1 M)		CaCl ₂ (0.1 M)		F-teste	CV (%)
	Hybrid	OP ^y	Hybrid	OP	Hybrid	OP	Hybrid	OP	Hybrid	OP		
No. of ears (ear·ha ⁻¹)	29,375	14,375	30,000	14,375	32,500	12,500	21,875	12,500	27,500	13,758	ns	23.5
Total unhusked ear wt (t·ha ⁻¹)	7.9	2.5	7.9	2.3	7.6	1.5	5.96	1.92	7.50	2.29	ns	26.2
Total husked ear wt (t·ha ⁻¹)	6.2	1.7	6.3	1.6	6.3	1.0	4.56	1.25	6.00	1.52	ns	27.3
Unhusked ear wt (g·ear ⁻¹)	0.4	0.2	0.4	0.2	0.3	0.2	0.37	0.21	0.39	0.24	ns	13.3
Husked ear wt (g·ear ⁻¹)	0.3	0.2	0.3	0.2	0.3	0.1	0.30	0.15	0.31	0.17	ns	12.2
Ear diameter (cm)	5.1	4.2	5.1	4.1	5.0	4.1	5.00	4.20	5.30	4.30	ns	5.3
Ear length (cm)	17.6	13.7	17.4	14.3	16.9	14.1	17.5	12.7	18.50	14.0	ns	13.8
Tip length (cm)	0.7	2.9	0.7	1.8	0.6	2.3	0.20	2.00	0.10	2.10	ns	55.0
Kernel wt (kg·ear ⁻¹)	0.1	0.1	0.2	0.1	0.2	0.1	0.18	0.08	0.17	0.09	ns	32.2
No. of rows (row·ear ⁻¹)	17.0	13.0	15.0	13.0	17.0	13.0	18	13	18	13	ns	5.2
No. of seed (seed·row ⁻¹)	34.0	30.0	35.0	26.0	33.0	25.0	34	27	34	27	ns	33.2

^yHibrix53' F₁ cultivar, ATS-5'OP cultivar, CV = coefficient of variation, ns = non-significant

Conclusions

The results of this study demonstrated consistent significant improvements in germination and seedling growth and development, in response to the different seed priming treatments, in both laboratory and field conditions, for both hybrid and OP seeds. However, a negative effect of seed priming was observed in the final germination percentage. Final yield was not affected by priming treatments for both corn cultivars. However, the hybrid cultivar gave a superior performance in relation to most aspects of growth performance, relative to the open pollinated cultivar. Also, the improvement in germination vigor was more pronounced in the artificial accelerated aged seed than in fresh seed of both cultivars. Based on the results, the study concludes that, H₂O, WV, NaCl and CaCl₂ can potentially be used as priming agents to improve germination and early seedling growth and establishment of both good quality as well as deteriorated seed of sweet corn, under favorable growing conditions and this practice can be done at a farmer level as WV, one of the most efficient priming agents can be produced at the household level.

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