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Germination Percentages of Different Types of Sweet Corn in Relation to Harvesting Dates

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Germination of sweet and super sweet corn is lower than normal corn due to the higher sugar and lower starch contents of kernels. Sweet corn seeds are easily deteriorated in the field under the unfavorable condition, therefore it is important to identify the optimal harvesting time for seed production. This trial was conducted to investigate the responses of germination percentage of *shrunken-2(sh2), brittle(bt), sugary(su),* and *sugary enhancer(se)* hybrids in relation to harvesting dates. Eight hybrids of four different gene sweet corns were harvested at 15, 20, 25, 30, 35, 40, 45, and 50 days after silking(DAS). Germination test was performed using paper towel method. Mean germination percentages across eight hybrids showed the highest value at 45 DAS. There were significant differences among genes and within gene for germination. *Shrunken-2* hybrid Mecca was higher than *su* hybrids for germination, indicating that *sh2* would not be poorer than *su*. Late harvesting beyond the optimal harvesting date might not be desirable because of more lodging and ear rots. Theoretical optimal harvesting date estimated from the regression equation was 40.9 DAS, however, practical date for harvesting would be a few days later than the estimated date if seedling vigor might be considered. Kernel dry weight per ear showed similar response to germination. Regression equation showed the highest kernel dry weight at 40.7 DAS. Significant correlations between kernel dry weight and germination were observed, impling that kernel dry matter accumulation would be an important factor for germination.

Key words: sweet corn, super sweet corn, harvesting date, germination, kernel dry weight

Among the various genes of sweet corns, four genes of sweet corn such as *sugary(su), shrunken-2(sh2), brittle(bt),* and *sugary enhancer(se)* have been grown for commercial production. Sweet and super sweet corn are vulnerable to environment condition during seed production. Seed deterioration of sweet corn in the field under the unfavorable environment is more common than field corn. It is desirable to harvest sweet corn seed at the optimal period for the high quality of seed. Corn researchers currently use a variety methods to determine the date of maturity of the grain. Kernel black layer formation is a commonly accepted indicator of physiological maturity (Carter & Poneleit, 1973; Daynard, 1972; Rench & Shaw, 1971). Growing degree days or calendar days accumulated during certain period have been used for prediction of maturity.

Higher sugar and lower starch contents of sweet corn kernel have raised problems of good germination and stand in the field. The seeds of sweet corn are smaller, lighter, more easily damaged and gave poorer germination than normal corn seeds. Lower germination of sweet corn might be due to the low total carbohydrates contents of the endosperm (Creech, 1965). Germination measurements of *sh2* seeds were significantly lower in both laboratory and field tests in comparison to *su, bt,* and normal seeds (Styer *et al.*, 1980). The *sh2* seeds are smaller, lighter and have a lower endosperm to embryo dry weight ratio than *su* or normal seeds (Wann, 1980). Those are also susceptible to fungal rots during germination in the field (Anderegg & Guthrie, 1981; Berger & Wolf, 1974; Halfon-Meiri, 1990). Styer & Cantliffe (1983) observed that *su* seeds were higher than *sh2* seeds for germination percentages and fully matured seeds for both *su* and *sh2* were higher in germination ability. It has been reported that excessively early or late harvested seeds were lower than moderately mature seeds for germination (Koehler *et al.*, 1934; Wilson & Trawatha, 1991). Germination percentages of *bt* and *sh2* seeds which were harvested at 16 days after pollination (DAP) were about 70% compared with almost 100% for *su* seeds (Styer *et al.*, 1980). However, seeds harvested at 18 DAP were more than 95% germination for all three genes. Mean germination across all harvesting dates ranging from 12 to 42 DAP for *bt, sh2, su,* and normal seeds were 96%, 77%, 92%, and 90%, respectively, indicating that *sh2* seed had a significantly lower germination. Their results showed also immature seeds had lower seedling weight and radicle length compared with fully mature seeds even though immature seed had higher

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germination. It was reported that high quality of corn seed was observed at the stage of achieving full maturity (Bennett *et al.*, 1988; Knittle & Burris., 1976). Kernel weight of *sh2* showed the maximum at 46 DAP, but *se* seeds were maximum at 53 DAP (Churchill & Andrew, 1984).

This trial was performed to observe the responses of germination percentages and kernel dry weight accumulation in relation to harvesting dates for different genes of sweet corn hybrids.

MATERIALS AND METHODS

Commercial sweet and super sweet corn hybrids homozygous for *sh2, bt, su,* and *se* were collected from the US seed companies (Table 1). Seeds for germination test were obtained by open pollination within each hybrid at the Waimanalo Research Station of the University of Hawaii in 1996. Plot size of each hybrid was 10 m in length with 10 rows. Individual plants were observed for silking date every morning and paper labels were put on the silked plants to identify the silking date. Five ears were harvested at a 5-day interval from 15 days after silking. Harvesting dates were 15, 20, 25, 30, 35, 40, 45, and 50 DAS. Harvesting was performed only in the middle part of each plot to reduce contamination from the adjacent plots. Contamination was easily identified because of normal seed production in case of contamination. Even though the seed production was done by open pollination within each hybrid the rate of contamination was almost negligible. Harvested ears were placed in a forced air drying oven at 35°C until complete dry.

Paper towel method was applied for germination test using 50 seeds with 2 replications. Both sides of paper towels were folded with seeds inside and rolled up and placed in room temperature (25-30°C). Boiled water was supplied to keep moist condition only in the bottom area of the rolled paper towel. Germination counts were made from 4 days after placement with 2-day intervals. Corn seeds which were 2 mm in radicle length were considered as germinated seeds. The germinated seeds were removed at each observation for 10 days.

Table 1. Sources of hybrids and days to silking.

Hybrid	Gene	Seed company	Days to silking
Forever	*sh2*	Asgrow Seed Co.	48
Mecca	*sh2*	Asgrow Seed Co.	48
HMX2353BB	*bt*	Harris Moran Seed	48
HS10	*bt*	Univ. of Hawaii	52
HMX4396REC	*su*	Harris Moran Seed	40
Sun Dance	*su*	Harris Moran Seed	40
Dancer	*se*	Johnny's Selected	52
Silver Choice	*se*	Burpee Seed	48

RESULTS AND DISCUSSION

Mean germination percentage across all hybrids was the highest at 45 DAS. The degree of germination increase was the highest between 20 DAS and 25 DAS (Table 2). Germination percentage at 35 DAS was 79.3%, showing no significant difference compared with 82.3% at 45 DAS. This result implied that sweet corn seed harvested at 35 DAS for the purpose of following planting might not have germination problem if only germination percentage would be considered. In case of breeding purpose, especially for the generation advance, early harvesting might be an important factor for sweet corn breeders. There were significant differences between sweet corn genes and within the same gene for germination percentage according to the maturing stages. Among the *shrunken-2* hybrids, hybrid Forever showed much different response than hybrid Mecca. Forever showed higher germinetion than Mecca at 15 DAS, however, Mecca indicated about 40% increase between 15

Table 2. Germination percentages at different harvesting dates.

Hybrid	Days after silking								Mean	$LSD_{0.05}$
	15	20	25	30	35	40	45	50		
Forever *(sh2)*	21.9	25.0	46.8	60.2	76.6	79.4	86.6	72.3	58.6	3.0
Mecca *(sh2)*	9.1	48.9	67.9	87.8	94.1	95.8	93.2	84.3	52.6	8.2
HMX2353BB *(bt)*	4.3	18.1	30.8	35.2	48.4	56.9	63.2	55.1	39.0	7.3
HS10 *(bt)*	15.9	52.7	74.9	90.3	90.8	94.7	90.8	87.0	74.6	3.7
HMX4396REC *(su)*	21.9	60.1	86.9	89.1	90.6	87.1	86.9	79.2	75.2	11.6
Sun Dance *(su)*	23.4	39.1	75.1	83.3	84.1	86.6	84.4	82.4	69.8	9.5
Dancer *(se)*	1.9	6.1	27.6	32.4	61.1	66.0	69.1	71.2	41.9	4.1
Silver Choice *(se)*	34.3	55.1	75.9	90.5	88.6	85.1	84.0	67.9	72.7	3.3
Mean	16.6	38.1	60.7	71.1	79.3	81.4	82.3	74.9		
$LSD_{0.05}$	6.5	6.4	11.4	7.2	6.8	8.3	5.9	7.5		

and 20 DAS, while Forever showed only 3% increase. This trend was also oserved in hybrids between HMX2353BB and HS10 which were *brittle*. It has been reported that *sh2* is poorer than *su* for germination. Hybrid Mecca which was *sh2* was quite high for germination compared with *su* hybrids. This indicated that germination problems of *sh2* would be improved if proper selection is applied. *Brittle* hybrid, HMX2353BB and HS10, were not superior to *sh2* hybrid for germination. This was different from the expected result which *bt* seed might be better than *sh2* seed. Among the super sweet corns HS10 which was developed at the University of Hawaii showed the highest germination percentage across all harvesting dates. Mean germination percentage of two *su* hybrids was higher than other genes of sweet corn as expected. Higher germination of *su* were reported by several researchers (Styer & Cantliffe, 1983; Styer *et al.*, 1980; Wann, 1980). Late harvesting at 50 DAS showed reduced germination in most hybrids with a exception of hybrid Dancer. This result would be explained due to lodging and ear rots. Plant lodging was severe in most hybrids and considerable ear rots were observed in lodged ears. It would be desirable to harvest sweet corn just after the maturity for seed production. Sweet corn is more vulnerable than normal corn for seed deterioration at the field condition under the unfavorable environment such as frequent rainfall. Regression equations between harvesting dates and germination percentages showed highly significant quadratic responses in all hybrids (Table 3). Theoretical optimal harvesting date estimated from the regression equation was 40.9 DAS across 8 hybrids. Optimal harvesting date of hybrid Silver which was *se* gene was 36.3 DAS, showing the shortest period from silking, and 61.9 days for hybrid Dancer, indicating the longest period from silking. From this trial, it would be concluded that sweet corn could be harvested from 40 DAS for the purpose of seed production. However, it had been reported that seedling vigor of early harvested seed was lower than late harvested seeds (Styer *et al.*, 1980). Therefore, optimum harvesting date for the practical purpose would be a few days later than the estimated date from the regression.

Responses of kernel dry weight per ear with harvesting dates were similar to those of germination percentages (Table 4). Mean kernel dry weight per ear across hybrids reached maximum at 30 DAS. Date for maximum dry weight was about five days earlier than that of germination

Table 3. Second degree polynomial equations between harvesting dates (X) and germination percentages (Y).

Hybrid	Gene	Regression equation	R	Estimated optimal harvesting days after silking
Forever	*sh2*	$Y=-0.0694X^2+6.358X-65.592$	0.969	45.8
Mecca	*sh2*	$Y=-0.144X^2+11.353X-125.378$	0.996	39.4
HMX2353BB	*bt*	$Y=-0.0438X^2+4.449X-53.570$	0.986	50.8
HS10	*bt*	$Y=-0.131X^2+10.301X-104.492$	0.989	39.3
HMX4396REC	*su*	$Y=-0.135X^2+10.035X-90.954$	0.960	37.2
Sun Dance	*su*	$Y=-0.109X^2+8.695X-83.286$	0.975	39.9
Dancer	*se*	$Y=-0.0383X^2+4.738X-66.564$	0.977	61.9
Silver Choice	*se*	$Y=-0.125X^2+9.075X-74.099$	0.989	36.3
Mean		$Y=-0.0994X^2+8.125X-82.998$	0.998	40.9

Table 4. Dry weight of kernels per ear at different harvesting dates.

Hybrid	Days after silking								Mean	$LSD_{0.05}$
	15	20	25	30	35	40	45	50		
	g/ear									
Forever *(sh2)*	18.8	32.2	45.2	47.8	50.2	51.4	52.0	58.2	43.8	12.0
Mecca *(sh2)*	25.8	29.4	47.2	45.0	42.4	40.8	55.60	55.4	42.8	5.8
HMX2353BB *(bt)*	18.8	29.0	39.4	35.0	41.0	43.6	38.8	36.8	35.3	3.4
HS10 *(bt)*	23.4	33.6	48.8	61.8	65.0	61.4	66.8	59.0	52.5	8.2
HMX4396REC*(su)*	23.0	36.4	54.0	67.0	60.4	52.4	59.0	60.0	51.5	9.2
Sun Dance *(su)*	23.2	36.2	42.0	55.2	55.2	48.6	41.4	56.4	44.8	6.4
Dancer *(se)*	22.4	42.6	48.6	56.4	53.2	47.2	52.4	45.8	46.1	7.5
Silver Choice *(se)*	17.8	37.8	52.6	61.4	67.0	62.0	68.0	66.6	54.2	6.4
Mean	21.7	34.7	47.3	53.0	54.3	51.0	54.3	54.8	46.3	
$LSD_{0.05}$	3.5	4.1	7.1	10.3	8.3	7.3	6.8	8.6		

Table 5. Regression equations between harvesting dates (X) and kernel dry weight per ear (Y).

Hybrid	Gene	Regression equation	R	Estimated optimal harvesting days after silking
Forever	*sh2*	$Y=-0.0373X^2+3.366X-20.642$	0.970	45.1
Mecca	*sh2*	$Y=-0.0113X^2+1.490X+7.733$	0.862	65.9
HMX2353BB	*bt*	$Y=-0.041X^2+3.122X-17.562$	0.947	38.1
HS10	*bt*	$Y=-0.0684X^2+5.534X-46.123$	0.984	40.5
HMX4396REC	*su*	$Y=-0.0666X^2+5.189X-38.001$	0.911	39.0
Sun Dance	*su*	$Y=-0.045X^2+3.587X-18.378$	0.853	39.9
Dancer	*se*	$Y=-0.0626X^2+4.559X-27.742$	0.923	36.4
Silver Choice	*se*	$Y=-0.0689X^2+5.729X-50.276$	0.984	41.6
Mean		$Y=-0.0493X^2+4.017X-25.652$	0.972	40.7

Table 6. Correlation coefficient between kernel dry weight per ear and germination percentage across harvesting dates.

Hybrid	Correlation coefficient
Forever *(sh2)*	0.880**
Mecca *(sh2)*	0.771*
HMX2353BB *(bt)*	0.854**
HS10 *(bt)*	0.966**
HMX4396REC *(su)*	0.934**
Sun Dance *(su)*	0.867**
Dancer *(se)*	0.599
Silver Choice *(se)*	0.909**
Mean	0.978**

*,**Significant at the 0.05 and 0.01 probability levels, respectively.

percentage. Increase of dry weight per ear between 15 DAS and 20 DAS was similar to that of between 20 DAS and 25 DAS. However, dry weight increase between 25 DAS and 30 DAS was reduced more than 50% compared with previous two stages of 5-day interval. This suggested that ear dry matter accumulation rate was the most vigorous before 25 DAS. Mean response of kernel dry weight per ear showed highly significant quadratic response with the maximum kernel dry weight at 40.7 DAS (Table 5). This estimated harvesting date was the same as that of germination percentage. The range of estimated date for maximum dry weight for all hybrids was from 36.4 to 65.9 days, showing similar response of germination percentage. Churchill & Andrew (1984) observed the maximum kernel weights of *sh2* and *su* seeds between 46 and 53 days after pollination. Significant correlations between kernel dry weights per ear and germination percentages were observed in most hybrids with an exception of hybrid Dancer (Table 6). This implies that dry matter accumulation would be an important determining factor for the seed germination.

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