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Effect of Water Stress on Production and Quality of Sweet Corn Seed[1]

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Additional index words. Zea mays, germination, cold test, coefficient of velocity, stalk rot

Abstract. **Four mid-season inbreds of sweet corn (*Zea mays* L.) were subjected to moderate or high soil moisture stress at tasseling, silking, or 2 weeks after silking. Soil moisture stress two weeks after silking was associated with a significant increase in the incidence of stalk rot symptoms 80 days after planting. Stalk rot and the percent seed-borne *Fusarium moniliforme* Sheld. were highly correlated. Stress at silking significantly reduced both yield components and seed quality attributes. Seed size distribution was influenced by the occurrence of water deficits, while the percent marketable seed was not.**

About 95% of the domestic and 85% of the world sweet corn seed is produced under furrow irrigation in southwestern Idaho. Proper irrigation management is essential in order to avoid reductions in seed yield and possibly seed quality.

The consumptive use of water by field corn has been found to be greatest during the period from tasseling to kernel formation (7, 11). Soil moisture stress during the silking stage has been shown to be especially detrimental to field (3, 6, 15) and sweet corn (9) yields. An initial attempt to determine the effect of moderate levels of soil moisture depletion on sweet corn seed yield, seed quality, and the relative water status of the plant itself was reported by El-Forgany and Makus (9). They reported that both seed yield and seed vigor in an early season sweet corn inbred were decreased when water stress occurred at silking and also showed that water stress, particularly around silking, was associated with an increase in the incidence of stalk rot, the major cause of lodging in production fields in southern Idaho. The following study examined the effect of both moderate and high levels of water stress on field performance of 4 mid-season inbreds and germination of their hybrid seed.

Materials and Methods

Field experiments were conducted on 4 mid-season sweet corn inbreds in 1978 on a Greenleaf silt loam soil at the University of Idaho Research and Extension Center, Parma. The pollen parent of 'Iochief' was the common pollinator of the inbreds studied. The seed parent of 'Iobelle', both the pollen and seed parents of 'Golden Cross Bantam', and the seed parent of 'Iochief' were identified respectively, as 1, 2, 3, and 4.

A split plot design having all 4 inbreds nested within 7 irrigation treatments was used. The experiment was replicated 4 times, making a total of 28 main plots and 112 sub-plots. Main plots consisted of 4 rows 18.3 m in length spaced 0.9 m apart. Each inbred was planted at random in 1 of these 4 rows at a density of 53,797 plants/ha and 3 pollinator rows separated the plots. Standard cultural practices were followed.

Irrigations were withheld until 2 levels of plant water stress were obtained. These levels were called moderate and high and represented a leaf water potential (LWP) difference of 2 bars.

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Moderate stress corresponded to 88% of available soil moisture depleted at a soil depth of 65 cm. Plants in the high stress treatments were exposed to an additional 5 days of water stress after the moderate level was reached. Plants were furrow irrigated as soon as they reached their respective moderate or high stress levels. Stress was imposed once at early tassel emergence, 50% silk, or 2 weeks after silking. Soil moisture in control plots was maintained above 60% of the total available moisture. The LWP of control plants were typically −8 bars or less (more positive).

Soil moisture content was determined by the gravimetric method. Representative samples from a depth of 65 cm were weighed, then oven dried at 105°C for 24 hr and reweighed. The LWP samples were taken between 0930 and 1100 hr the day of maximum stress, 3 days after irrigation, and 7 days after irrigation. The top fully expanded leaf of 3 randomly selected plants of each inbred were sampled. Three 1.8 cm leaf disks were punched from the middle of the leaf between the margin and the midrib. The LWP of these discs was measured using the Campbell J-14 press (Campbell Scientific, Logan, Utah 84321).

Visual stalk rot readings were taken 80, 95, and 100 days after planting. At maturity, plant height and the vegetative dry weight of plants without their ears were determined.

Kernel-row number/ear, ears/ha, ear weight/plant, cob weight/ha, cob length and total seed yield/ha were determined for each plot. All weights were determined as air dried weights. Seeds were sized into 4 classes (large flat, small flat, large round, small round) to obtain seed distribution data. The seed was later combined to form 2 size classes, flats and rounds, in order to have sufficient seed for the seed germination and seed-borne *Fusarium moniliforme* tests. Three germination tests were made.

Standard germination test. AOSA procedures (1) were slightly modified in this test. Four replications of 100 seeds from each plot, inbred, and seed size were placed on a Schleicher and Schuell 478 filter paper in 15 cm glass Petri dishes. Twenty-five ml of 0.05% aqeuous sodium hypochlorite adjusted to a pH of 7 (10) were added the first day and an additional 10 ml the third day of the test. The seeds were placed in a germinator with a daily cycle of 16 hr at 20°C followed by 8 hr at 30°. Germination counts based on radicle emergence after 7 were recorded.

Coefficient of velocity. This test and the standard germination test were conducted simultaneously on the same seed. Germination counts were taken beginning at day 2 and continued daily for 5 more days. The rate of germination was determined by the method of Kotowski (12).

Cold test. Three replicates of 100 seeds from each plot, inbred, and seed size were germinated in 6×17×11 cm plastic bedding containers as previously reported (9). The procedure was modified by reducing the bottom layer of sand (grade EI-16, Weldon Silica Co., Emmett, ID) to 200 cm^3. After the seeds were added, they were covered to a depth of 2.5 cm with 600 cm^3 of sand, then moistened with 250 ml of distilled water to 70% of saturation. Light was provided after the 10th day to limit coleoptile elongation. Emergence counts were taken after 14 days.

Seed-borne Fusarium moniliforme *test.* Two 100-seed samples from each treatment inbred, replication, and seed size of the non-stressed controls, and moderate stress levels at both tasseling and 2 weeks after silking were tested. This test was not conducted on the remaining treatments due to lack of seed. A modified deep freezing and agar plate method of Singh et al. (16) was used. The seeds were surface sterilized for 5 min in 0.5% aqueous sodium hypochlorite. Each 100 seed sub-sample was then allowed to imbibe 20 ml of distilled water for the next 24 hr at 21°C and then frozen for 24 hr to terminate germination. After thawing, 10 seeds each were placed in a sterile 10 cm Petri dish containing about 10 ml of 1.5% potato dextrose agar. After 5 days incubation under continuous near ultraviolet light the pink colonies of *Fusarium moniliforme* were counted.

The comparison of means by the LSD for split-plot designs is based on those given by Steel and Torrie (17).

Results and Discussion

The LWP was significantly affected by both the level and time of soil moisture stress. At tasseling and silking, the high water stressed plants of inbreds 1, 2, and 4 had lower (more negative LWPs than did the moderately stressed plants (Table 1). The LWPs generally increased 1 to 2 bars 3 days after maximum stress and were about the same as the controls 7 days after maximum stress. The LWPs were lowest (most negative) in plants stressed at silking. Peak evapotranspiration rates at silking may contribute to the greater deficits in LWP (6, 7). In greenhouse studies (4) there was a trend for LWP readings to increase with physiological age of the leaf.

Both stress levels at silking resulted in highly significant reductions in plant height, kernel-row number/ear, ear weight/plant, ears/ha, cob length, and total seed yield/ha (Table 2). Plant vegetative dry weight was not significantly affected by water stress. The accumulation of carbohydrates in the stalk due to a reduced ear sink may explain why water stress did not affect plant vegetative dry weight (2, 8). Significant increases in the percent stalk rot 80 days after planting were shown for plants stressed 2 weeks after silking (Table 3). Significant inbred differences in the percent stalk rot occurred 80, 95 and 100 days after sowing. Stalk rot symptoms later in the season may have been masked by early senescence brought on by an apparent nitrogen deficiency. Though not statistically significant, the percent seed-borne *Fusarium moniliforme* in seed from plants that were moderately stressed at tasseling and 2 weeks after silking was about twice that of the control. The inability to detect significant differences was probably related to the small sub-sample sizes available. The amount of seed-borne *Fusarium* in hybrid seed was also found to be inbred dependent. A significant linear correlation of r=0.95 was found between the percent stalk rot and seed borne *Fusarium moniliforme*. Makus et al. (13) observed a similar relationship between the field occurrence of stalk rot and the presence of seed-borne *Fusarium moniliforme* in the inbred 'Luther Hill'. The presence of stalk rot symptoms was always increased by water stress (9).

The association between high levels of seed-borne *Fusarium* and water deficits in corn plants may be related to several factors. The organism is ubiquitous, being spread by wind and

Table 1. Effect of water stress on the leaf water potential of 4 sweet corn inbreds the day of maximum water stress.

Time of stress	Relative stress level	Leaf water potential (Negative bars)			
		Inbred 1	Inbred 2	Inbred 3	Inbred 4
Tasseling	Moderate	6.5	6.6	7.1	6.9
	High	8.7	9.5	7.5	9.2
Silking	Moderate	12.2	12.9	13.6	13.1
	High	14.8	14.6	--	15.0
2 wks after silking	Moderate	11.0	11.4	11.4	12.1
	High	9.5	12.4	12.1	12.1
Means		10.4	11.2	10.3	11.4

LSD 5% = 1.0, 2 inbred means.
LSD 5% = 1.6, 2 treatment means.
LSD 5% = 2.4, any 2 means.

Table 2. Effect of water stress on the field performance of four sweet corn inbreds pooled across inbreds or treatments.

Time of stress	Relative stress level	Plant ht at maturity (cm)	Vegetative[z] dry wt at maturity (g)	Kernel-row number/ear	Ear wt/plant (g)	Total seed yield/ha (kg)	Ears/ha[y] (×1000)	Cob wt/ha (kg)	Cob length (cm)
Tasseling	Moderate	109.0	155.0	12.0	23.6	773	42.4	375	12.2
	High	98.6	148.0	11.4	12.7	358	29.2	236	11.6
Silking	Moderate	107.4	161.9	10.5	9.3	229	25.5	206	11.5
	High	106.8	154.1	10.8	6.6	157	20.1	154	11.3
2 wks after silking	Moderate	115.9	156.8	12.3	19.5	611	33.5	306	11.8
	High	115.1	149.3	12.2	23.7	771	35.4	341	11.8
Control		121.4	171.8	12.3	27.4	883	42.3	405	12.3
LSD 5%		8.8	NS	0.8	7.5	260	11.5	107	0.4
LSD 1%		12.1	NS	1.1	10.3	357	15.1	147	0.5
Inbreds									
1		112.0	158.3	12.9	15.6	475	30.1	226	10.8
2		117.6	117.6	9.3	17.7	664	34.8	279	10.7
3		103.8	123.7	12.2	14.7	487	30.2	282	12.5
4		109.0	200.3	12.1	22.0	704	35.2	329	13.1
LSD 5%		3.3	11.6	0.5	2.9	113	3.7	35.7	0.4
LSD 1%		4.5	15.4	0.6	3.8	150	4.9	47.3	0.5

[z]Does not include ear wt.

[y]Includes all fertilized ears.

Table 3. Effect of water stress on the presence of stalk rot and subsequent seed-borne *Fusarium moniliforme* in 4 sweet corn inbreds pooled across inbreds or treatments.

Time of stress	Relative stress level	Stalk rot (%)			Seed-borne *F. moniliforme* (%)
		80 days	95 days	110 days	
Tasseling	Moderate	5.4	67.7	79.6	25.7
	High	6.0	65.4	85.1	–
Silking	Moderate	4.7	67.2	81.8	–
	High	4.5	69.3	86.8	–
2 wks after silking	Moderate	6.3	66.5	78.1	25.7
	High	7.4	68.2	80.5	–
Control		3.6	66.9	80.7	12.3
LSD 5%		2.1	NS	NS	NS
Inbreds					
1		4.4	64.0	81.4	10.8
2		7.8	78.5	92.9	31.2
3		7.6	81.4	99.1	23.0
4		1.6	45.3	53.8	19.4
LSD 5%		0.7	3.2	3.9	12.0

rain (14). Corn earworm larvae can be active on silks of mid- and late-season inbreds, particularly those delayed in silking by water mismanagement. Corn earworm fed-on ears are subject to secondary feeding by picnic beetles, *Glischrochilus quadrisignatus,* known vectors of *Fusarium moniliforme* (18). The growth of *Fusarium* spp. is most aggressive at osmotic potentials of –5 to –35 bars (5), in contrast to the corn plant which ceases to grow after about –8 bars water potential.

Seed grade distribution was significantly altered by water stress while percent marketable seed was not (Table 4). Stress at silking produced increases in the percent of small round and decreases in the percent of large and small flat seed. Large round seed tended to increase.

The subsequent performance of hybrid seed was detrimentally affected when produced under water deficits. Water stress at silking significantly reduced the rate of seed germination (Table 5). No statistically significant differences were found for the final germination count and cold test. However, stress at silking tended to reduce germination rates in the cold test.

Flat seed from each inbred germinated more rapidly than round seed. This agrees with earlier unpublished data by Makus and P. Torell (Idaho-Eastern Oregon Seed School, Boise; December 5, 1975) which showed that flat seed of the sweet corn inbred 'Luther Hill' germinated faster than round, regardless

Table 4. Effect of water stress on size distribution and percent marketable hybrid seed from 4 sweet corn inbreds pooled across inbreds or treatments.

Time of stress	Relative stress level	Seed distribution (%) Large flat	Small flat	Large round	Small round	Marketable seed (%)
Tasseling	Moderate	20.4	13.7	18.0	41.0	93.2
	High	20.2	15.1	15.9	42.1	93.2
Silking	Moderate	17.8	7.8	19.1	48.8	93.5
	High	18.7	10.5	15.5	49.0	93.7
2 wks after	Moderate	22.3	14.2	13.4	40.8	90.7
silking	High	21.6	17.7	12.0	39.9	91.2
Control		23.4	16.4	14.8	40.0	94.6
LSD 5%		3.4	4.8	NS	6.6	NS
Inbreds						
1		23.8	5.4	20.8	43.3	93.3
2		12.2	20.0	19.4	44.9	96.6
3		13.7	20.8	13.8	42.5	90.8
4		32.8	8.3	8.1	41.7	90.9
LSD 5%		2.8	3.5	3.7	NS	1.7

Table 5. Germination tests of hybrid sweet corn seed from stressed and non-stressed plants pooled across inbreds and seed sizes, treatments and seed sizes, or treatments and inbreds.

Time of stress	Relative stress level	Germination (%) Day 2 count	Day 4 count	Final count	Coefficient of velocity	Cold test
Tasseling	Moderate	27.3	95.2	97.7	50.6	83.8
	High	25.2	94.7	97.6	49.5	82.5
Silking	Moderate	20.4	93.7	97.1	47.2	81.0
	High	19.1	93.3	97.2	45.9	76.7
2 wks after	Moderate	29.1	95.6	97.9	51.6	83.3
silking	High	31.0	96.3	98.5	52.7	82.2
Control		29.9	95.1	97.0	52.2	84.5
LSD 5%		3.8	2.1	NS	2.3	NS
Inbreds						
1		31.1	95.9	98.7	52.2	84.9
2		20.5	90.3	94.3	46.9	78.9
3		16.9	97.7	98.7	45.7	84.3
4		35.8	95.4	98.9	55.2	83.0
LSD 5%		2.6	1.3	0.9	1.5	3.4
Sizes						
Rounds		15.1	93.0	97.4	43.1	81.7
Flats		38.1	96.9	98.0	57.5	83.8
LSD 5%		1.2	0.7	NS	0.6	NS

of seed weight. Water uptake of round seed was higher than that of flat seed measured 7 days after imbibition.

Germination tests suggest that even under ideal conditions, the germination rate of seed from sweet corn plants stressed at silking will be reduced. Further research may determine whether lower germination is related to (a) anatomical changes such as pericarp thickness, or (b) physiological alterations as in assimilate content and/or hormonal imbalances.

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Observations on Leaf Characteristics of Afghanistan Pine[1]

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Additional index words. Pinus brutia, morphology, epicuticular wax, wax fine-structure

Abstract. **Observations on leaf morphology and on the fine-structure and quantity of epicuticular wax of a newly introduced (Plant Introduction (PI) 303638) Afghanistan pine (*Pinus brutia* Ten.) indicated that needles were borne 2 or 3 per fascicle with 1.7- to 4-fold more 3- than 2-needled fascicles depending on the flush of growth. Needles were curved and twisted, margins serrulate, and apices acute. An amorphous epicuticular wax, about 180±48 $\mu g\ cm^{-2}$, covered the needles. Crystalline platelet or fiber-like wax occurred in irregular patches, frequently around stomata. Stomata on both abaxial and adaxial surfaces were deeply depressed and in rows parallel to the long axis of the needle. In many stomata the antechamber was partially occluded with fiber-like wax. Thin-layer chromatograms indicated that the more polar constituents, namely fatty acids, *sec*-alcohols and esters were most prevalent, while only traces of alkanes, ketones and aldehydes were present.**

Seeds of an unidentified species of pine collected in the Herat Region of Afghanistan were introduced into the United States in 1960 (7). Seedlings of this accession (PI 271431) were widely distributed to cooperators for evaluation in 1961. The young tree grows rapidly and is tolerant to drought, high temperature and frost (7, 8, 16). Its attractive form and rapid growth in semi-arid regions make it potentially useful for Christmas trees and for shelterbelts in the arid southwestern United States (7, 8).

There is some question whether this pine belongs to *P. brutia* Ten. (W.B. Critchfield, E. L. Little, F. G. Meyer, personal communications) or to the closely related Aleppo pine, *P. halepensis* Mill. (7). Classification is complicated because 3 collections were made. The original one was labelled PI 271431. Subsequent collections also made near Herat were identified as PI 303638 and 362153. The 3 collections may or may not have been from the same source. Classification is further complicated by opinions as to whether *P. brutia* is an established species. Turrell (20) and others (1, 3, 6) list *P. brutia* as *P. halepensis* var. *brutia* (Tenore) Elwes and Henry, while Mirov (17) considers it an independent species. For this report, we use the name *P. brutia* as suggested by Meyer (personal communication).

Here we report on the morphological characteristics of the leaves and on the quantity, fine-structure and chemistry of the epicuticular wax. These data should be useful in further taxonomic and drought tolerance studies of this plant.

Materials and Methods

General. All leaf samples were collected from 5-year-old seedlings of PI 303638 at the University Farm at Las Cruces, New Mexico. Total moisture per annum averaged 50-60 cm, 20 to 30 cm from natural precipitation and 30 cm from 3 to 4 irrigations.

Gross morphology. Branches from current season's growth, consisting of 3 flushes, were removed from each of 5 representative trees on December 3, 1976. Fasicicles were removed in sequence from each flush of growth and the number of needles and length of the longest needle in each fascicle was determined. Scale needles at the base of each flush of growth frequently persisted but were not studied.

Length of needles in 100 2- and 3-needle fascicles collected at random from current season's growth and width of 20 randomly selected needles were measured. The width of the adaxial, or flat (4), surface of semi-circular needles and the length of a line representing a chord formed with the arc of the curved surface (abaxial), as well as the two flat (adaxial) surfaces of triangular needles were measured with a binocular dissecting scope using an eyepiece reticle.

Surface morphology and leaf structure. Leaves from 2- and 3-needle fascicles were selected from the median portion of the third flush of growth, frozen immediately on dry ice and then lyophilized and stored in a desiccator. Segments about 5

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