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Cultivar and Storage Temperature Effects on the Shelflife of Blackberry Fruit.

P. PERKINS-VEAZIE,[1] J. K. COLLINS,[1] AND J. R. CLARK[2]

Abstract.

'Arapaho,' 'Choctaw,' 'Navaho' and 'Shawnee' blackberries (*Rubus* sp.) were stored at constant temperatures of 2 °, 5 °, or 10 °C for 21, 14, or 7 days respectively, to determine shelflife. 'Navaho' consistently had fewer leaky berries than 'Choctaw' or 'Shawnee' for all storage intervals and temperatures. 'Arapaho' and 'Navaho' had a high percentage of firm berries (77 to 86%) after storage at 5 or 10 °C. All fruit held in storage at 10 °C prior to freezing had fewer red berries than fruit held at 2 °C. At all storage temperatures, 'Arapaho' and 'Navaho' berries were more marketable, and had a higher soluble solids/titratable acidity compared to 'Choctaw' and 'Shawnee.' Of the four cultivars, 'Navaho' had the fewest red berries after freezing. In all cultivars, titratable acidity declined, pH increased, and soluble solids remained the same for berries held 7, 14, or 21 days at 10, 5, and 2 °C, respectively. Total sugars were not different among cultivars and declined slightly during 21 d storage at 2 °C (550.6 and 426.2 mg/g dw, respectively). Initially, glucose, fructose, and sucrose were present in all cultivars (46.6, 48.3, 5.1%, respectively). After 21 d storage at 2 °C, glucose levels increased slightly (to 54.5%), fructose levels decreased (to 45.5%), and sucrose declined (to 0%). The excellent shelflife of 'Navaho' and 'Arapaho' blackberries indicates that fruit of these cultivars should be suitable for long distance shipment.

About 90% of blackberries produced in the United States are used for processing, especially those grown in the Pacific Northwest (21). Only about 364 ha east of the Rocky Mountains are used to produce blackberries and these fruit are mostly sold for fresh markets (3; M. Baker, Overton, Texas, personal communication). The rapid loss of blackberry fruit quality following harvest has limited the use of blackberries for fresh market.

The release of semi-erect, thornless cultivars from the USDA breeding program in Beltsville, Md., and of erect thorny and thornless cultivars from the University of Arkansas breeding program has improved fresh market blackberry quality. 'Chester Thornless,' a semi-erect blackberry, is firm and has a good shelf life (1, 4). 'Arapaho' and 'Navaho' blackberries are thornless and ripen earlier than the semi-erect 'Chester Thornless' (10, 11). 'Navaho' remains firm after 7 d storage at 2°C (13). There are no published reports on the quality of 'Arapaho' fruit during storage. Production of 'Navaho' and 'Arapaho' thornless blackberries for fresh market has increased dramatically in the South, and is increasing in the Pacific Northwest. Unlike processing blackberries, fresh market blackberry production is usually in small plantings of <5 ha. Although the recommended storage temperature for blackberries is 0 to 1 °C (5), most small-acreage growers lack adequate cooling facilities, and fruit are often stored at 5 to 10 °C.

Earlier, we found that 'Cheyenne' and 'Navaho' blackberries at the shiny black stage of ripeness could be held for 7 d at 2 °C with relatively little loss of quality (13). The purpose of this experiment was to determine the limits of storage temperatures and duration on the quality of commercially ripe fruit from erect-type blackberry cultivars.

[1]United States Department of Agriculture, Agriculture Research Service, South Central Agriculture Research Laboratory, Lane, OK 74555

[2]Department of Horticulture, University of Arkansas, Fayetteville, AR 72701

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Materials and Methods

Plant material

Fruit from two thorny blackberry cultivars, Choctaw and Shawnee, and two thornless cultivars, Arapaho and Navaho, were harvested at Lane, Okla. in 1995. Growing practices recommended for the region were followed, and no fungicides were applied after bud break.

The erect-type blackberry cultivars used in this study have overlapping or identical maturity dates. In southern Oklahoma 'Choctaw' ripens first, in late May to early June, followed by 'Arapaho' in early to mid-June, 'Shawnee' in mid-late June, and 'Navaho' in mid-June to early July. The ripening period ranges from 2 to 4 weeks, depending on the cultivar. Harvest dates were arranged to obtain early and mid-season berries for each cultivar. Firm, fully black fruit, free from decay, injury, or defects, were harvested twice (one week between harvest) for each cultivar from 2-year-old plots before 10:00 a.m. Fruit were harvested into 250 ml polyethylene clamshell boxes (Ultra Pac, Rogers, Minn. 55374, model 3535) fitted with absorbent paper pads.

Storage treatments

Three replicates per cultivar, harvest date, storage temperature, and storage duration, consisting of clamshell boxes containing ca 140 g of fruit per box (a total of 3 boxes), were stored for 7 days at 10 °C; 7 or 14 days at 5 °C; or 7, 14 and 21 days at 2 °C. Storage fruit were weighed and rated individually for the presence or absence of decay, leakage, or red drupelet discoloration, and for firmness. Red drupelet discoloration negatively affects the visual appeal of blackberry fruit (berries appear to be half-ripe). Leakage was measured by the presence or absence of a red spot from juice leakage clustered under each fruit when gently rolled on white paper. If more than three drupelets were red, red discoloration was ranked as present. Firmness was judged subjectively by gently squeezing individual berries. Berries were rated on a scale of 1 to 5 where 1 = firm, 2 = slightly soft, 3 = soft, 4 = very soft, and 5 = mushy. The percentage of firm fruit was determined by summing the percent fruit rated at 1 or 2. Marketable fruit were determined by the formula 100% – {sum[%leaky + % decayed + % soft (rated 4 and 5)]/3}.

For each harvest and after each storage interval, 100 g of berries per replicate were frozen and held at –20 °C until compositional analysis. Prior to compositional analysis fruit were thawed, and the number of frozen berries appearing red and black were counted. Forty g of thawed fruit from each treatment were ground in a Waring blender and 0.5 ml of the macerate was placed on the stage of an Atago PR-100 digital refractometer (NSG Precision Cells Inc., Farmingdale, N.Y.) for determination of soluble solids concentration (SSC). An additional 10 g of puree was placed in a beaker with 90 ml of ddi water and the samples were titrated with 0.1 N NaOH to pH 8.1. Titratable acidity (TA) was calculated as percent citric acid. To determine anthocyanin content, 5 g of blackberry puree was extracted twice with 20 ml aliquots of acidified (0.02 M HCl) 90% ethanol. Maximum absorbance was read at 532 nm on a spectrophotometer (Shimazdu UV 120-01, Columbia, Md.) and data expressed as absorbance units/gram frozen weight.

For sugar composition analyses, ~75 g of fruit per replicate, with 4 replications per cultivar, were harvested from the field directly into 50 ml plastic containers (Consolidated Plastics Co., Twinsburg, Ohio) on day 0, then frozen immediately at –80 °C. After each storage period, ~75 g of fruit, from each box, were frozen as above. All fruit were then freeze-dried, ground with mortar and pestle, and filtered through plastic mesh to eliminate seeds. Sugars were extracted from 0.1 g of freeze dried tissue and determined by HPLC (Shimazdu, Columbia, Md.) following previously reported methods (8, 14).

At each harvest, blackberries were stored at 2, 5, or 10 °C. Storage temperatures were analyzed separately and temperatures were not compared statistically, as the storage intervals within each temperature were of inconsistent duration. The experiment was designed as a split plot within each storage temperature, with cultivars as the main plot arranged in a completely randomized design and with storage days as sub-plot. The experiment was repeated over harvest dates. Data were subjected to analysis of variance, and mean separation was performed by least significant difference (LSD), $P \leq 0.05$.

Results and Discussion

Within storage temperatures, differences in weight loss among cultivars were generally slight with few exceptions (Table 1). The weight loss in this study was considerably lower than that previously reported for blackberry shelflife studies (2), probably due to the prompt cooling and minimal handling of fruit in our study.

The percent decayed berries increased with storage interval (Table 1). The percentage decayed berries in all cultivars after 7 d at 5 °C was at least doubled that of 7 d at 2 °C. With the exception of 'Navaho,' the percentage decayed berries of cultivars held 7d at 10 °C was at least tripled that of 7 d at 5 °C. A similar effect of temperature on decay development has been reported for strawberries (7). Fresh blackberries must have <1% decay to meet grading standards (22); fruit of all cultivars held for 7 d at 2 °C met this standard. In this study, we deliberately omitted plant fungicide sprays to challenge cultivar response. Therefore, the decay in this experiment may be higher than that encountered in a commercial situation where preharvest fungicides are routinely applied.

'Navaho' fruit consistently had fewer leaky berries than 'Shawnee' among all temperatures and storage periods (Table 1). After 14 d at 2 °C or 5 °C, greater than 70% of 'Shawnee' berries were leaky, compared to <25% of 'Navaho' berries. These results agree with other reports, where 'Navaho' fruit consistently had fewer leaky berries than other cultivars, even when stored under less than optimal temperatures (13, 14).

The percentage of firm berries clearly showed cultivar differences, even after only 7 d at 2 °C (Table 1). The number of firm 'Navaho' and 'Arapaho' berries was unusually high at 5 and 10°C. Berries held at these temperatures often felt more firm than those held at 2 °C. This may be due to the higher weight loss at the higher temperatures, resulting in subsequent epidermal cell dessication and a firmer "feel" for these berries (19).

The incidence of red discoloration of berries was lower overall for 'Navaho' compared to the other cultivars (Table 1). Storage interval and storage temperature had little effect on red drupelet incidence.

Within each storage temperature, 'Arapaho' and 'Navaho' had more marketable fruit than 'Shawnee' (Table 1). 'Arapaho' and 'Navaho' had > 80% marketable fruit after 14 days at 2°C, or after 7 days at 5°C. After 7 days at 10°C, only 49.5 to 58.9% of 'Shawnee' and 'Choctaw' berries were marketable while 77.6 to 81.2% of 'Navaho' and 'Arapaho,' respectively, were marketable.

Soluble solids concentration of 'Navaho' ranged from 11.1 to 13.3% over all storage durations and temperature combinations and was consistently higher relative to the 8.1 to 10.1% SSC of other cultivars (Table 2). Values are similar to those reported for these cultivars at other locations (9, 10, 11, 12). The high SSC of 'Navaho' fruit is similar to that reported for 'Hull Thornless,' a semi-erect thornless blackberry (16).

Titratable acidity declined for all cultivars during storage, but cultivar differences in TA were inconsistent with storage interval (Table 2). A decline in TA has also been found in 'Chester Thornless' blackberries held for 7 days at 25 °C (23).

'Navaho' and 'Arapaho' had a higher SSC/TA (12.6 to 17.7) in stored fruit than 'Choctaw' or 'Shawnee' (9.1 to 12.2) (Table 2). This high SSC/TA ratio is similar to that of the semi-erect 'Black Satin' and 'Chester Thornless' (17, 18). A high SSC/TA is considered desirable and an indication of good eating quality of small fruits (20). Changes in SSC/TA with storage were due to reduced TA, rather than to increased SSC. The pH of blackberries,

Table 1. Cumulative weight loss and subjective ratings on fruit of blackberry cultivars following storage at 2, 5, or 10 °C.

	Storage temperature (C)							
	2				5			10
	Days of storage							
Cultivar	7	14	21	LSD (P ≤ 0.05)	7	14	LSD (P ≤ 0.05)	7
Cumulative weight loss (%)								
Arapaho	2.6	4.1	5.6	0.3	2.7	5.5	0.3	4.0
Choctaw	2.7	4.6	6.6	0.2	2.8	5.0	0.4	4.6
Navaho	2.2	3.5	5.2	0.4	3.4	6.0	0.2	3.1
Shawnee	2.3	4.1	5.9	0.3	3.2	5.0	0.3	3.6
LSD (P ≤ 0.05)	0.2	0.6	0.6		0.4	1.0		0.7
Decayed berries (%)								
Arapaho	0.6	3.7	5.1	4.5	1.5	21.9	4.2	10.7
Choctaw	0.0	3.7	5.9	6.6	1.8	17.7	7.1	7.0
Navaho	1.0	10.9	6.6	7.5	9.7	4.9	8.8	6.4
Shawnee	3.9	7.7	19.0	7.4	8.0	17.9	13.0	28.7
LSD (P ≤ 0.05)	3.8	6.9	6.4		7.2	13.2		11.8
Leaky berries (%)								
Arapaho	15.3	25.6	43.3	15.3	27.2	52.2	14.6	33.8
Choctaw	30.9	42.2	56.2	14.8	51.0	56.9	8.2	72.5
Navaho	6.9	9.7	38.5	23.1	7.4	21.9	11.3	32.7
Shawnee	41.6	72.7	81.5	19.0	40.5	82.7	20.5	58.7
LSD (P ≤ 0.05)	19.3	13.4	20.5		15.9	20.6		25.1
Firm berries (%)[z]								
Arapaho	69.4	82.4	76.5	12.8	78.8	79.8	29.3	77.2
Choctaw	56.8	65.0	57.2	14.7	68.9	50.1	8.5	56.2
Navaho	88.6	89.6	65.3	13.5	86.6	80.4	22.7	82.8
Shawnee	41.9	37.0	29.2	12.1	64.2	29.2	24.8	36.0
LSD (P ≤ 0.05)	11.6	11.4	11.8		10.8	12.0		12.1
Berries with red drupelet discoloration (%)								
Arapaho	25.5	24.0	31.1	17.3	20.1	11.6	15.0	16.9
Choctaw	30.8	47.0	23.9	10.0	51.8	23.6	13.0	20.6
Navaho	6.8	18.2	12.4	12.9	2.2	4.1	4.0	2.9
Shawnee	29.6	34.9	27.4	13.0	16.4	33.2	16.5	30.8
LSD (P ≤ 0.05)	12.6	22.4	14.2		15.4	12.0		16.6
Marketable berries (%)[y]								
Arapaho	84.5	84.3	76.0	8.7	83.4	68.6	12.2	77.6
Choctaw	75.3	73.0	65.0	2.2	72.0	58.5	7.6	58.9
Navaho	93.6	89.7	73.4	17.4	89.8	84.5	19.5	81.2
Shawnee	65.5	52.2	42.9	9.3	71.9	42.8	14.9	49.5
LSD (P ≤ 0.05)	10.4	9.7	11.1		9.8	17.0		12.9

[z]Firm berries = sum of berries rated 1 or 2.

[y]Marketable berries = 100 – sum [% leaky + % decayed + % soft (rated 4 and 5)]/3.

Table 2. Compositional analysis of blackberry puree following fruit storage at 2, 5, or 10 °C.

		Storage temperature (C)							
		2				5			10
		Days of storage							
Cultivar	Prestorage	7	14	21	LSD ($P \leq 0.05$)	7	14	LSD ($P \leq 0.05$)	7
		Soluble solids concentration (% SSC)							
Arapaho	9.2	9.9	9.8	9.8	0.3	9.7	10.1	1.3	9.6
Choctaw	9.0	9.0	8.4	8.8	0.2	9.0	7.5	1.2	8.1
Navaho	12.8	13.3	12.0	12.6	0.1	12.5	11.1	0.2	12.8
Shawnee	9.3	9.4	9.4	9.5	0.4	9.7	9.5	1.2	8.7
LSD ($P \leq 0.05$)	0.4	0.3	0.3	0.3		0.6	0.9		0.8
		Titratable acidity (% TA)							
Arapaho	1.34	0.99	0.93	0.79	0.14	0.91	0.58	0.16	0.75
Choctaw	1.37	1.04	1.17	0.80	0.06	0.87	0.72	0.03	0.82
Navaho	1.25	0.88	1.04	0.88	0.03	1.04	0.85	0.08	0.72
Shawnee	1.19	1.08	1.05	0.94	0.19	0.96	0.79	0.11	0.87
LSD ($P \leq 0.05$)	0.08	0.17	0.15	0.16		0.29	0.20		0.20
		Soluble solids/titratable acidity (SSC/TA)							
Arapaho	8.2	11.6	13.6	13.2	1.8	11.7	11.5	3.5	14.0
Choctaw	7.3	9.1	9.7	11.3	0.4	9.5	9.2	1.5	9.9
Navaho	10.8	15.1	16.1	15.6	0.4	13.4	12.6	1.3	17.7
Shawnee	7.7	9.1	12.2	11.3	2.0	10.5	9.4	5.2	10.2
LSD ($P \leq 0.05$)	0.7	1.8	1.9	2.0		4.4	2.4		2.3
		pH							
Arapaho	3.31	3.10	3.29	3.47	0.20	3.30	3.63	0.23	3.51
Choctaw	3.34	3.44	3.30	3.61	0.22	3.68	3.57	0.16	3.68
Navaho	3.16	3.23	3.40	3.52	0.15	3.27	3.69	0.08	3.71
Shawnee	3.21	3.13	3.34	3.38	0.21	3.33	3.63	0.13	3.40
LSD ($P \leq 0.05$)	0.15	0.10	0.10	0.14		0.35	0.20		0.16
		Anthocyanin content (absorbance units/g frozen wt)							
Arapaho	89.6	108.1	98.0	99.7	20.0	112.4	123.1	21.2	125.1
Choctaw	87.6	91.9	82.8	82.5	4.6	112.1	103.9	5.6	137.9
Navaho	100.3	112.9	111.8	133.5	7.3	134.8	160.8	8.4	185.4
Shawnee	102.9	115.6	103.5	105.3	17.9	135.5	131.0	22.7	150.3
LSD ($P \leq 0.05$)	7.9	12.5	7.9	26.8		22.4	22.4		12.9
		Frozen red berries (%)							
Arapaho	22.1	18.9	18.3	12.2	9.9	1.5	0.0	3.3	1.6
Choctaw	19.6	9.7	16.4	9.0	0.1	11.6	1.1	2.5	0
Navaho	6.6	4.2	6.0	0.0	0.1	5.6	0.0	0.2	0
Shawnee	15.1	17.8	13.6	17.6	15.4	5.6	0.0	0.2	0
LSD ($P \leq 0.05$)	2.2	12.9	21.7	11.6		6.7	5.8		0

Table 3. Changes in sugar composition in fruit of blackberry cultivars following storage at 2, 5, or 10 °C.

		Storage temperature (C)							
		2				5			10
		Days of storage							
Cultivar	Prestorage	7	14	21	LSD (P ≤ 0.05)	7	14	LSD (P ≤ 0.05)	7
					Total sugars (mg/g dry weight)				
Arapaho	582.2	428.1	461.3	489.8	76.6	505.1	550.0	51.9	509.1
Choctaw	511.1	458.8	388.3	345.3	98.1	442.0	360.0	128.8	468.0
Navaho	541.6	475.0	520.6	421.9	112.3	565.6	516.3	54.4	480.4
Shawnee	567.3	490.2	486.8	447.7	62.5	453.1	541.4	93.6	513.8
LSD (P ≤ 0.05)	105.1	84.2	93.7	83.3		76.3	61.3		99.1
					% Sucrose				
Arapaho	2.5	1.1	0.0	0.0	0.9	1.2	0.0	1.3	1.2
Choctaw	7.8	2.2	0.2	0.0	2.3	0.0	0.2	0.2	1.3
Navaho	3.7	1.4	0.0	0.1	1.4	1.5	0.1	1.1	0.9
Shawnee	6.3	2.0	0.1	0.0	1.2	2.1	0.1	2.0	2.4
LSD (P ≤ 0.05)	3.7	1.8	0.1	0.0		1.8	0.1		2.0
					% Glucose				
Arapaho	48.2	50.3	47.2	53.1	8.2	50.6	52.1	1.6	51.8
Choctaw	44.6	52.4	52.3	58.5	2.9	56.4	56.5	3.7	53.5
Navaho	48.2	49.1	50.8	53.3	1.9	51.7	50.4	1.6	50.7
Shawnee	45.5	49.0	50.8	53.2	1.2	42.5	52.3	13.4	50.1
LSD (P ≤ 0.05)	2.0	1.9	10.8	1.9		8.1	1.4		1.9
					% Fructose				
Arapaho	49.3	48.4	52.7	46.9	8.2	48.1	47.9	1.0	46.9
Choctaw	47.6	45.4	47.5	41.5	3.2	43.6	43.3	3.7	45.1
Navaho	48.0	49.4	49.2	46.7	1.6	48.1	48.1	1.0	48.4
Shawnee	48.2	48.9	49.1	46.8	1.2	55.4	47.6	13.7	47.5
LSD (P ≤ 0.05)	2.1	1.3	10.8	1.9		8.2	1.3		1.6

while variable among samples, generally increased with storage time (Table 2).

Anthocyanin content was cultivar-and storage temperature-dependent (Table 2). Seven days storage was sufficient to increase anthocyanin content by 48 to 86% at 10 °C. At 5 °C, only 'Navaho' and 'Arapaho' berries increased significantly in anthocyanin content after 14 d storage compared to initial (prestorage) values. Total anthocyanin content of these cultivars was similar to values reported for 'Black Satin' and 'Dirksen Thornless' (16). Anthocyanin content was not correlated with the incidence of red drupelet discoloration (data not shown), and storage temperature had little effect on the incidence of red drupelet discoloration. Anthocyanin appeared to accumulate in 'Navaho' fruit when held for a long time at low temperatures (2 °C) or for short times at high temperatures (7 d at 10 °C). Although part of this increased pigmentation may be due to weight loss and subsequent anthocyanin concentration, the anthocyanin content increase is likely too great (86%) to be accounted for by the 5% weight loss.

The percentage berries turning red after freezing was lowest for 'Navaho' in prestored fruit (Table 2). Fruit held at 5 or 10 °C storage temperatures or for 21 d at 7 °C had very few red berries after freezing. Although fresh 'Shawnee' fruit had a large number of berries with red discoloration after storage (Table 1), the number of frozen red berries (prestorage) differed little from 'Arapaho' or 'Choctaw' (Table 2).

Low fruit pH has been implicated as a cause of the undesirable reddening in frozen blackberries (6). Our data partially support this conclusion, as the pH tended to be higher in berries stored longer or held at higher storage temperatures.

The total sugar content of freshly harvested fruit ranged from 511.1 to 582.2 mg/g dry weight among blackberry cultivars (Table 3). After storage at 2 °C for 21 d, total sugars declined 22.6% in compared to the prestorage amounts, probably from metabolism of sugars. All cultivars had a small amount of sucrose (1 to 5% of total sugars), with sucrose declining to almost undetectable amounts after 14 d of storage at 2 or 5 °C. Sucrose was initially higher in 'Choctaw' and 'Shawnee,' but significant differences among cultivars did not occur at any temperature after 7 d of storage. The glucose content in prestored berries was slightly higher in 'Arapaho' and 'Navaho' while stored 'Choctaw' had more glucose than other cultivars in stored fruit. Glucose levels generally increased during storage for all cultivars, while fructose declined slightly, regardless of storage temperature or length of storage. The fructose content of 'Choctaw' fruit was slightly lower than other cultivars before and after storage. Our sugar values are similar to those reported for other studies with blackberries (14, 15).

Summary

'Arapaho' fruit were similar to 'Navaho' berries in quality, although not quite as firm as 'Navaho' berries following storage. 'Arapaho' berries provide an early season cultivar suitable for long distance (3 days) transport for fresh markets. 'Shawnee' and 'Choctaw' fruit deteriorated rapidly, especially at 5 or 10 °C, and should be sold quickly if cooling facilities are lacking. Recommended maximum storage intervals for the cultivars studied (assuming constant temperatures) are 10 d for Navaho, 7 d for 'Arapaho' and 4 d for 'Choctaw' or 'Shawnee' when held at 2 °C. When held at 5 °C, fruit of these cultivars should be held for only half of storage periods indicated for 2 °C.

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Verification of the True 'Witte' Pecan and Naming of the 'Martzahn' Cultivar

L. J. GRAUKE,[1] T. E. THOMPSON,[2] BILL REID,[3] W. A. GUSTAFSON[4]

Abstract

A discrepancy in the identification of the pecan [*Carya illinoinensis* (Wangenh.) K. Koch] cultivar 'Witte' has been resolved by a combination of techniques, including comparison of voucher specimens and evaluation records, supplemented by isozyme analysis. The origin of the error is traced in hopes of extricating accurate cultivar evaluation information on the historic cultivar, from evaluation records of a previously unnamed accession. A name, 'Martzahn', is given to that accession to facilitate separation of the two entities.

A discrepancy has been resolved in the identification of the historic Iowa pecan cultivar, 'Witte.' The resolution of this discrepancy is important for several reasons: misidentified trees can be correctly identified; propagation of the error can be stopped; evaluation data incorrectly attributed to the cultivar can be eliminated from its record; and finally, corrected or new appellations can be attached to inventories previously misidentified. In order to accomplish this, the history of both the cultivar and the error must be traced.

Historical

The pecan cultivar 'Witte' originated as a native seedling in Burlington, Iowa (10). The original tree was found as the result of a systematic effort by J. F. Jones to find pecans adapted to a northern climate. In 1914, Jones "engaged the services of a competent man to gather pecans" near Muscatine, Iowa (10). None were found to be worthy of propagation. That same autumn, nuts from Burlington, Iowa were sent to G. H. Corsan in Toronto, Canada, who was also searching for hardy, north-

United States Department of Agriculture, Agricultural Research Service, Pecan Breeding & Genetics, College Station, TX 77879.

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[1]Research Horticulturist and Curator, National Clonal Germplasm Repository for Pecans and Hickories. ljg@tamu.edu
[2]Research Geneticist.
[3]Pecan Specialist, Pecan Experiment Field, Kansas State University, Chetopa, KS 67336-0247.
[4]Professor of Horticulture, Southeastern Research & Extension Center, University of Nebraska, Lincoln, NE 68583-0714.