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Organic Blackberry Cultivar Trials at High Elevation and in High pH Soil in the Southwestern United States

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Abstract

Two semi–erect, three erect floricane-fruiting and one primocane-fruiting blackberry (*Rubus* L. subgenus *Rubus* Watson) cultivars were evaluated in high tunnels and in the field at Alcalde, NM. Semi–erect cultivars Triple Crown and Chester Thornless were planted at 1.5 × 2.5 m in a 5.0 × 12.2 m high tunnel with an identical field planting. Erect cultivars Ouachita, Natchez and Navaho, and primocane-fruiting cultivar Prime-Ark® 45 were planted at 0.6 × 1.7 m in another 5.0 × 12.2 m high tunnel with an identical field planting. Comparing all cultivars, yield of floricane-fruiting cultivars was reduced by winter damage while the primocane-fruiting cultivar Prime-Ark® 45 had reliable fall crops in the high tunnel each year in northern New Mexico. Based on four winters' weather, canes of semi–erect and erect blackberry cultivars overwintered well when mid-winter temperatures dropped to -15 °C, but canes were damaged when temperatures reached -20 °C. 'Chester Thornless' was more cold hardy than 'Triple Crown', and 'Ouachita' was more cold hardy than 'Navaho' and 'Natchez' in the field. 'Triple Crown' produced 1-1.5 times more yield than 'Chester Thornless' in the high tunnel and in the field, while 'Ouachita' had the highest yield in 2015 and the highest cumulative yield from 2012–2015 among the three erect cultivars tested in the high tunnel, while in the field 'Natchez' had the highest cumulative yield. 'Prime-Ark® 45' produced well in the fall in the high tunnel but not in the field. 'Navaho' had small plants and low yields both in the high tunnel and in the field. In northern New Mexico or similar areas with a short growing season, 'Triple Crown', 'Ouachita', 'Natchez' and 'Prime-Ark® 45' are recommended for high tunnels while 'Triple Crown', 'Natchez', and 'Ouachita' are recommended for field planting.

Blackberry (*Rubus* L. subgenus *Rubus* Watson) and raspberry (red raspberry- *Rubus ideaus*) are closely related and together they are called brambles or caneberries. Generally, blackberry is more heat tolerant than raspberry. Raspberry production is prevalent in regions with cool summers like the West Coast. Washington, Oregon and California account for over 80% of raspberry production in the United States, whereas blackberry production is more widely distributed, including southern states with hot summers like Florida, Georgia and Texas (USDA NASS, 2014; Strik et al. 2007). Blackberries have trailing, semi–erect and erect growing habits. In general, erect cultivars and semi–erect cultivars are more cold hardy than trailing types and trailing cultivars are not suitable for cold areas (Black and Lindstrom, 2014; Weber, 2013; Westwood, 1993). Clark (1992) conducted a survey of 13 Southern states and the dominant cultivars were erect cultivars (78%) and the rest were semi–erect. Trailing blackberries are more adapted to the mild climate of the Pacific Northwest and California in the U.S. (Finn et al., 2005a, 2005b, 2005c and 2005d).

Brambles have performed well in high tunnels and yields can be more than double that of those planted in the field (Thompson et al., 2009; Demchak, 2009; Domoto et al., 2008; Rom et al., 2010). By using high tunnels, the harvest season of floricane-fruiting blackberries can be advanced and the harvest season of primocane-fruiting blackberries can be extended (Demchak, 2009; Lamont

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et al., 2003; Rom et al., 2010). There is very limited blackberry research in the Southwest (Walser and Guldan, 2006). The objectives of this study were to evaluate semi–erect, erect and primocane-fruiting blackberry cultivars, compare high tunnel and field planting, and recommend suitable cultivars for growers in northern New Mexico or similar regions with short growing seasons and high pH soils.

Materials and Methods

This study was conducted at New Mexico State University's Sustainable Agriculture Science Center at Alcalde, NM (Lat. 36°05'27.94" N, long. 106°03'24.56" W, and 1735 m elevation). Two semi–erect cultivars, Triple Crown and Chester Thornless, three erect cultivars, Natchez (Clark and Moore, 2008), Navaho, and Ouachita (Clark and Moore, 2005), and one primocane-fruiting cultivar Prime-Ark® 45 (Clark and Perkin-Veazie, 2011) were used in this experiment. All plants were tissue cultured plugs from North American Plants (Lafayette, OR). The two existing high tunnels used in this study were built at the Center with dimensions of 5.0 × 12.2 m. The main structure consisted of vertical metal posts 1.2 m apart and 1.2 m above ground, with two inch plastic pipe (polyvinyl chloride) arched for the upper part with highest point of 2.9 m. The high tunnel had one door at each end and roll-up sides. The cover used was 8 µm Solarig 172 woven plastic (J&M Industries, Inc., Ponchatoula, LA). The two semi–erect cultivars were in one high tunnel while the erect and primocane-fruiting cultivars were in another identical high tunnel. For the high tunnel with semi–erect cultivars, there were two rows in the high tunnel with a randomized complete block design with three replications at a planting density of 1.5 × 2.5 m. For the high tunnel with primocane-fruiting and floricane-fruiting erect cultivars, there were three rows using a randomized complete block design at 0.6 × 1.7 m planting density. There were identical plantings in the nearby field for each high tunnel. All plants were planted in May 2011 and the plantings were in a USDA certified organic field and managed organically. Weeds were managed manually both in the high tunnels and in the open field and pests were scouted weekly during the growing season and managed organically as needed (Bushway et al., 2008).

The soil type was a Fruitland sandy loam (coarse-loamy, mixed, superactive, calcareous, mesic Typic Torriorthents) with 1.6-1.7% soil organic matter in the top 15 cm of soil and the soil pH was 7.9-8.0 (1:1 water extraction) (Yao et al., 2015). About 56 kg/ha nitrogen (N) as cotton seed meal (7.0N-0.9P-0.8K) was applied before planting for all plantings. Two 1.27 cm diameter polyethylene drip irrigation tubing lines with emitters 30 cm apart delivering 3.78 L per h were installed along each row after planting and plants were watered once per week for 4 h or as needed during the growing season each year. Organic fish fertilizer (Neptune's Harvest fish fertilizer 2.0N-1.7P-0.8K, Gloucester, MA) was applied through fertigation at two week intervals at a rate of 1.9 L each time per high tunnel or field planting, two to three times for 2011-2012 and four to five times in June and July for 2013-2015. Semi–erect cultivars were in a single 1.5 m high trellis system in each row, while two 1.2 m high single wire trellises at 0.6 m apart were used for each row to hold the plants of erect cultivars in the row. Semi–erect cultivars were pinched when the canes reached the top of trellis while the canes of 'Prime-Ark® 45' were also pinched when the canes were 90-100 cm in height (Strik et al., 2012). 'Prime-Ark® 45' was grown only for a primocane crop with all canes pruned to the ground while dead floricanes were removed for other cultivars in March each year. The sides of both high tunnels were kept open year round except in Oct. when sides were lowered at night for frost protection.

Cane winter damage was assessed visually in May of each year. If no bud break (lateral emergence) occurred, they were judged as dead. Fruit from all plants in each plot was harvested twice per week or as necessary from 2012-2015. Total fruit weight and weight of 30 fruit from each plot were recorded for each harvest. Fruit weight and fruit yield data of erect and primocane fruiting cultivars were analyzed with ANOVA by Statistix (Tallahassee, FL). Since there was only one high tunnel and one field planting for each blackberry type, they were analyzed separately and could not be compared statistically. For semi-erect cultivars, due to limited degrees of freedom, standard deviation was calculated for yield data instead of ANOVA. Standard deviation was also calculated for cane winter damage data.

Results and Discussion

Weather data and plant winter damage. Fig. 1 presents winter and spring daily minimum temperature data from 2011 to 2015. Blackberry plant performance was closely related to weather conditions in northern New Mexico. The winters of 2011/12 and 2012/13 both had minimum temperatures of -20°C or lower in Dec 2011 and Jan 2013. The winter of 2013/14 had fewer extremes in mid–winter than the winters of 2011/12 and 2012/13, but there were more late frosts (0 °C or lower) in April and May 2014 (Fig. 1). Regardless of growing habit or cultivar, field plantings had more winter cold injury than the high tunnel plantings (Table 1). Plants suffered more winter cane damage in 2012 and 2013 than in 2014 and 2015 (data not shown for 2014 and 2015). Even though the canes in high tunnels were green in spring of 2012 and 2013, the buds on the floricanes of some plants never broke and laterals only emerged on the lower 30-50 cm of floricanes. Clark et al. (2012) mentioned that winter injury of floricane-fruiting blackberry cultivars is a big concern in mid-western and northern U.S. It is also true in the Southwestern U.S. at high elevation areas such as in northern New Mexico. The floricane-fruiting blackberry crop is not reliable in these areas because of winter minimum temperatures.

For the two semi–erect cultivars tested, 'Chester Thornless' was more cold hardy than 'Triple Crown' in the field in 2012 (Table 1). In New York, 'Chester Thornless' was also reported more cold hardy than others (Weber, 2013). For erect cultivars, Ouachita was more cold hardy than 'Natchez' and 'Navaho' in both 2012 and 2013 (Table 1) in the field. In 2014 and 2015, all floricanes over-

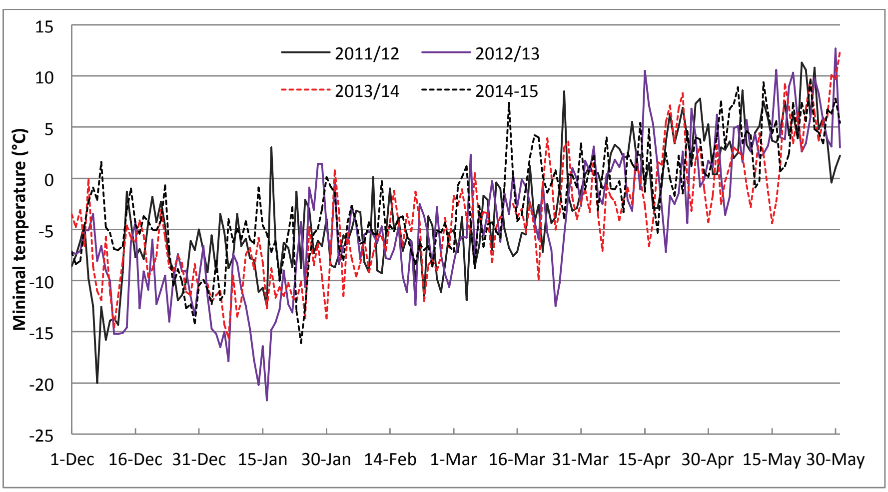

Figure 1. Daily air minimum temperatures for Dec. to May from 2011-2015 at Alcalde, NM.

Table 1. Blackberry cane winter damage in 2012 and 2013 at Alcalde, NM.

Type	Location	Cultivar	Winter damage 2012 [z]	Winter damage 2013
Semi-erect	Field	Chester Thornless	2.6 ± 0.18 [y]	3.1 ± 0.25
		Triple Crown	4.7 ± 0.18	3.2 ± 0.25
	High Tunnel	Chester Thornless	1.0 ± 0.09	1.0 ± 0.00
		Triple Crown	1.2 ± 0.09	1.0 ± 0.00
Erect	Field	Natchez	2.7 ± 0.19	4.4 ± 0.24
		Navaho	3.4 ± 0.19	4.1 ± 0.23
		Ouachita	2.1 ± 0.19	3.3 ± 0.23
	High Tunnel	Natchez	1.1 ± 0.04	1.1 ± 0.10
		Navaho	1.0 ± 0.04	1.1 ± 0.09
		Ouachita	1.0 ± 0.04	1.0 ± 0.09

[z] Damage Rating Scale: 1. No damage; 2. One year old cane tip damaged; 3. Up to half length of cane damaged; 4. More than half of cane length damaged; 5. All canes dead.
[y] Mean ± SE

wintered well in high tunnels for semi–erect and erect cultivars. For the field plantings, there was minor floricane tip damage for both semi–erect and erect cultivars.

Based on weather data from 2011-2015 and blackberry cane winter damage data, floricanes overwintered well at -15 °C but they were damaged at -20 °C. Strong winds and huge temperature fluctuations in the spring in northern New Mexico can also contribute to floricane injury. Even though the sides of high tunnels were open in winter, they still provided protection with warmer daytime temperatures and reduced wind speed. Others also reported that blackberry winter damage was reduced in high tunnels (Demchak, 2009; Strik et al., 2007). However, high tunnels did not provide enough protection for floricanes in mid–winter when temperatures dropped to -20 °C or lower in this study.

Frost damage occurred occasionally during the trial period. The frost on 29 May 2012 killed new primocanes and forced the plants to produce new primocanes and primocane branching. We noticed damage to early blooming flowers for 'Natchez' and 'Ouachita' due to the mid–May frosts both in 2014 and 2015.

Yield. In 2012, the first harvest year after planting, all erect cultivars had a very light crop while there was no crop for semi–erect cultivars (Table 2, Table 3). 'Prime-Ark® 45' had a reliable fall crop each year despite the severe winter weather conditions, while the yields of floricane-fruiting cultivars were related to plant age and weather conditions (Table 2). In the high tunnel, there were no significant differences among 'Prime-Ark® 45', 'Ouachita' and 'Natchez' both in 2013 and 2014, only 'Prime-Ark® 45' had a significantly higher yield than 'Navaho' in 2013, and both 'Prime-Ark® 45' and 'Ouachita' had a greater yield than 'Navaho' in 2014 (Table 2; Fig. 2A). In 2015, the fifth year after planting, 'Ouachita' yielded an average of 5.6 kg/plant, higher than 'Navaho', but not significantly different from 'Natchez' and 'Prime-Ark® 45'. The high yield of 'Ouachita' in a mature stand was also documented in other locations (Clark and Moore, 2005, 2008). 'Navaho' had the smallest plants and lower accumulated yield than 'Ouachita' in the high tunnel (Table 2).

For the field planting, 'Natchez' had higher cumulative yield than 'Navaho' and 'Prime-Ark® 45' (Table 2). 'Natchez' appeared to produce similar yield in the high tunnel and in the field from 2013-2015 while 'Ouachita' and 'Prime-Ark® 45' yielded higher in the high tunnel. 'Navaho' had the smallest plants among the four cultivars in the field planting. Perhaps because of high elevation and a shorter growing season in northern New Mexico, 'Prime-Ark® 45 grew better in the high tunnel than in the field as described in other areas with shorter growing seasons (Clark, 2008). A high tunnel extended the growing season of the primocane-fruiting cultivar Prime-Ark® 45 and ensured that fruit reached maturity for harvest; however, 'Prime-Ark® 45' is not a reliable cropper for planting in the open field in northern New Mexico as in New York and Minnesota (Clark, 2008). 'Prime-Ark® 45' avoided the winter damage issue for floricane-fruiting cultivars in cold areas (Clark, 2008), but early maturing primocane-fruiting cultivars with good fruit quality, especially thornless ones, are needed for short growing season areas (Clark, 2008; Clark et al., 2012).

For the yields of semi–erect cultivars, the improved cold hardiness of 'Chester Thornless' was reflected in the yield in the high tunnel in 2013. While in years with mild winters, 'Triple Crown' produced nearly two- to three-fold the yield of 'Chester Thornless' in the high tunnel in 2014 and 2015, respectively (Table 3 and Fig. 2B). In the field, 'Triple Crown' also produced higher yields than 'Chester Thornless' in both 2014 and 2015. The yield of 'Triple Crown' in the high tunnel in this study is close to that reported

Table 2. Yield of erect and primocane blackberry cultivars in high tunnel (HT) and field from 2012 to 2015 at Alcalde, NM. The yields from high tunnel or field each year were analyzed separately.

Location		Yield (kg/plant)					kg/ha	kg/ha
	Cultivar	2012	2013	2014	2015	2012-15	2015	2012-15
HT	Prime-Ark 45	0.21	1.10 a[z]	1.31 a	2.16 ab	4.78 ab	21,088	46,693
	Ouachita	0.27	0.54 ab	1.33 a	5.55 a	7.68 a	54,279	75,075
	Natchez	0.39	0.42 ab	1.03 ab	2.57 ab	4.41 ab	25,106	43,065
	Navaho	0.02	0.14 b	0.50 b	2.01 b	2.67 b	19,622	26,093
Field	Prime-Ark 45	0.23	0.12 a	0.16 b	0.78 b	1.30 b	7,664	12,670
	Ouachita	0.03	0.05 b	0.26 b	1.63 a	1.96 ab	15,897	19,201
	Natchez	0.04	0.04 bc	0.98 a	2.00 a	3.06 a	19,592	29,877
	Navaho	0.04	0.01c	0.55 ab	0.50 b	1.10 b	4,927	10,764

[z] Means within each column and location not followed by common letters are significantly different at $P \leq 0.05$, by Fisher's protected LSD.

Table 3. Yield of semi-erect blackberry cultivars in high tunnel (HT) and field from 2013 to 2015 at Alcalde, NM. (n=3, mean ± SE)

	Yield (kg/plant)				kg/ha
	2013	2014	2015	2013-15	2013-15
HT-Triple Crown	0.35±0.13	9.45±2.04	10.16±2.63	19.96±4.76	53,219
HT-Chester Thornless	0.82±0.57	4.91±0.54	3.73±1.10	9.46±1.14	25,227
Field-Triple Crown	0.02±0.02	2.41±0.39	7.96±1.42	10.39±1.80	27,696
Field-Chester Thornless	0.06±0.07	1.59±0.19	2.78±0.92	4.42±1.08	11,782

in high tunnels in Pennsylvania (Demchak, 2009).

High tunnels advanced the harvest season for semi–erect cultivars and erect cultivars by one to three weeks and extended the harvest season of the primocane-fruiting cultivar for two weeks in the fall (Fig. 2A and 2B). Similar results have been reported in other states (Demchak, 2009; Rom et al., 2010; Thompson et al., 2009). The harvest season of ‘Natchez’ in the field planting was similar to that in the high tunnel in 2014 which could be related to the mid-May frost that killed the early blooms and reset the blooming process. *Fruit size*. ‘Triple Crown’ fruit matured earlier and was larger than ‘Chester Thornless’, while ‘Chester Thornless’ was firmer than ‘Triple Crown’ (Table 4, Fig. 2B). ‘Prime-Ark® 45’ and ‘Natchez’ had bigger fruit while ‘Navaho’ had the smallest fruit overall (Table 4). Fruit sizes in high tunnels appeared bigger than those in the field for all cultivars except ‘Chester Thornless’ which had similar size in the field and in the high tunnel in 2014 (Table 4). Larger fruit in high tunnels was also reported elsewhere (Thompson et al., 2009) and for raspberries (Yao and Rosen, 2011). Clark et al. (2012) mentioned a substantial genotype × environment interaction for three primocane-fruiting cultivars -- smaller fruit for ‘Prime-Jan®’, ‘Prime-Jim®’ and ‘Prime-Ark® 45’ in Arkansas and bigger fruit in cool areas like Oregon. High temperatures (>32°C) during bloom and fruit development stage negatively impact fruit size and quality (Clark et al., 2012). In northern New Mexico, it can be hot (>32°C) during the day but always cool at night and the fruit size of ‘Prime-Ark® 45’ was similar to or larger than erect or semi–erect cultivars tested. It seems not only the maximum temperature, but also the diurnal temperature difference plays a role in primocane-fruiting blackberry fruit development and fruit quality.

In summary, semi–erect, erect and primocane-fruiting blackberries all can be planted in northern New Mexico, but if minimum temperature drops to -20 °C or lower, floricane damage can be expected. Even high

Table 4. Blackberry fruit weight of different cultivars grown in high tunnels (HT) and field in 2014 at Alcalde, NM.

Cultivar	HT (g)	Field (g)
Prime Ark® 45	7.0 a[z]	6.3 a
Natchez	6.8 ab	5.0 ab
Ouachita	6.6 b	4.8 ab
Navaho	4.0 c	3.0 b
Triple Crown	7.4 a	6.0 a
Chester Thornless	3.1 b	3.3 b

[z] Means within each column and fruiting type (erect or semi-erect) not followed by common letters are significantly different at P ≤ 0.05, by Fisher's protected LSD.

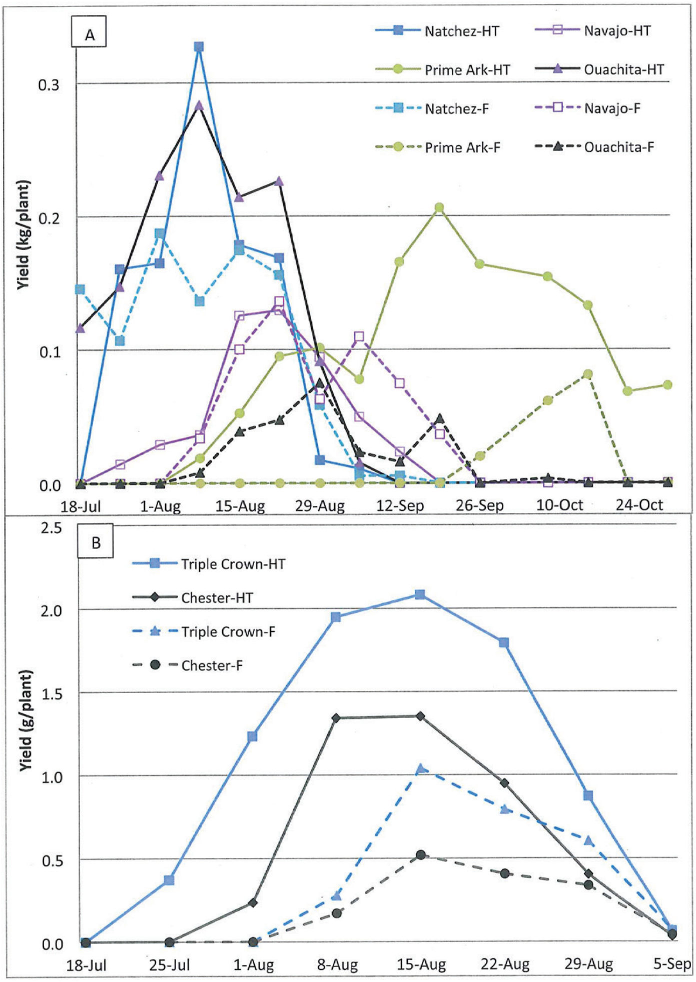

Figure 2. Seasonal yields of erect and primocane-fruiting blackberry cultivars (A), and semi–erect cultivars (B) grown in high tunnels (HT) and the field in 2014 at Alcalde, NM.

tunnels could not protect floricanes from temperatures lower than -20 °C. For cultivar Prime-Ark® 45, if it is considered as primocane-fruiting only as in this trial, winter extreme temperatures do not affect its yields in northern New Mexico.

Blackberries produced higher yields in high tunnels. Semi–erect 'Triple Crown', erect 'Ouachita' and 'Natchez' and primocane-fruiting 'Prime-Ark® 45' performed well in high tunnels. Semi–erect and erect cultivars together with 'Prime-Ark® 45' would greatly extend the fruit supply season which is critical for those selling their produce at local farmers markets. For field planting, 'Triple Crown', 'Natchez', and 'Ouachita' are good choices. 'Prime-Ark® 45' does not perform well in short growing season areas in open field plantings. Blackberry still is a risky fruit in northern New Mexico and can be severely damaged in winters when minimal temperatures drop to -20 °C or lower.

Selecting a protected area or planting them in high tunnels would reduce this risk considerably.

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