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‘APF-45’ Primocane-fruiting Blackberry

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‘APF-45’ was introduced to broaden the choices of this innovative, primocane-fruiting blackberry (*Rubus* L. subgenus *Rubus* Watson) type. This is the third in the University of Arkansas Prime-Ark® Brand Primocane Fruiting Blackberry cultivar line and will be marketed as Prime-Ark® 45. It follows the release of ‘APF-8’ and ‘APF-12’ (marketed as Prime-Jan® and Prime-Jim®, respectively) in 2004 (Clark et al., 2005). This unique type of blackberry fruits on current-season canes (primocanes) and second-season canes (floricanes). Traditional blackberry cultivars fruit on floricanes, requiring canes to be overwintered to produce a crop. This fruiting habit has the potential to expand blackberry production much like that which has occurred for primocane-fruiting red raspberries (*Rubus ideaus* L.). These first two primocane-fruiting cultivars were intended primarily for home-garden production and for limited commercial trial evaluations. ‘APF-45’ is the first primocane-fruiting cultivar with commercial-quality fruit characteristics with postharvest potential for shipping. It may broaden production both seasonally and geographically to strengthen blackberry growing and marketing.

Origin

‘APF-45’ resulted from a cross of APF-1 × ‘APF-12’ (Fig. 1) made in 2000 at the University of Arkansas Fruit Research Station, Clarksville. The original plant was selected in June 2002 in a seedling field at the same location during evaluation of floricane fruits. It was tested as selection APF-45. At the time of selection, it was noted to have the firmest fruit compared with other primocane-fruiting selections found at that time in the primocane-fruiting blackberry breeding program.

Description and Performance

After selection, two 6.1-m plots of ‘APF-45’ were established at the Fruit Research Station [west–central Arkansas, lat. 35°31′58′ N and long. 93°24′12′ W; U.S. Dept. of Agriculture (USDA) hardiness zone 7a] in Summer 2002. Plots were established by moving the original plant along with planting root cuttings collected from the original plant. Observational data were taken on the selection in these plots at the time of floricane fruiting in 2004 (fruit not rated in 2003 as a result of very few present on young plants) and continued through 2010. Single plots of primocane-fruiting cultivars APF-8 and APF-12 along with floricane-fruiting cultivars Natchez and Ouachita were also present for comparison in this planting and observational data were collected on these during this same evaluation period. In all plantings, standard cultural practices for erect blackberry production were used including annual pre-emergence and postemergence herbicide applications and annual spring nitrogen fertilization (56 kg·ha^{-1} N) using ammonium nitrate. The primocane genotypes received another application of the same amount of ammonium nitrate after the floricane crop was completed, which was in early July. All genotypes had primocanes tipped at 1.1 m height two times each season, usually in mid-June and late July or early August. Dormant pruning of primocane-fruiting genotypes consisted of removing dead floricanes and also removing primocane tissue to a point below the fruiting/flowering area on the primocanes. All primocane-fruiting genotypes were allowed to produce both flori- and primocane crops in these plots. Floricane-fruiting genotypes received dormant pruning, which consisted of removing dead floricanes and pruning lateral branches to ≈0.4 m in length. All plantings received a single application of liquid lime sulfur (94 L·ha^{-1}) at budbreak for control of anthracnose [*Elsinoë veneta* (Burkh.) Jenkins]. This was the only fungicide applied to any plantings in any year. All plots were irrigated as needed using overhead sprinkler irrigation.

Data collected included primocane first date of flowering and first ripe fruit date. Also, floricane fruit ratings were taken for all genotypes based on a rating scale of 1 to 10, in which 10 = best, for 7 years (2004 to 2010) for firmness (as measured subjectively by hand in the field on eight to 10 berries with a rating of 10 indicating very firm) and flavor (subjectively rated by tasting berries in the field with 10 being exceptional flavor). Plant ratings for vigor (1 to 10 with a rating of 7 to 10 acceptable), health (1 to 10 with 10 = excellent health), and erectness (1 to 10 with 10 = very erect) were conducted one time each year for 7 years (2004 to 2010) during the floricane-fruiting season.

Replicated trials were established at Clarksville (Fruit Research Station) in May of each year in 2004, 2005, and 2007. These trials consisted of either two or four replications. Plots in these trials were 3.1 m in length containing five plants produced from root cuttings spaced at 0.6-m intervals. The cultivars APF-12, Natchez, or Ouachita were included for comparison in the trials. Cultural

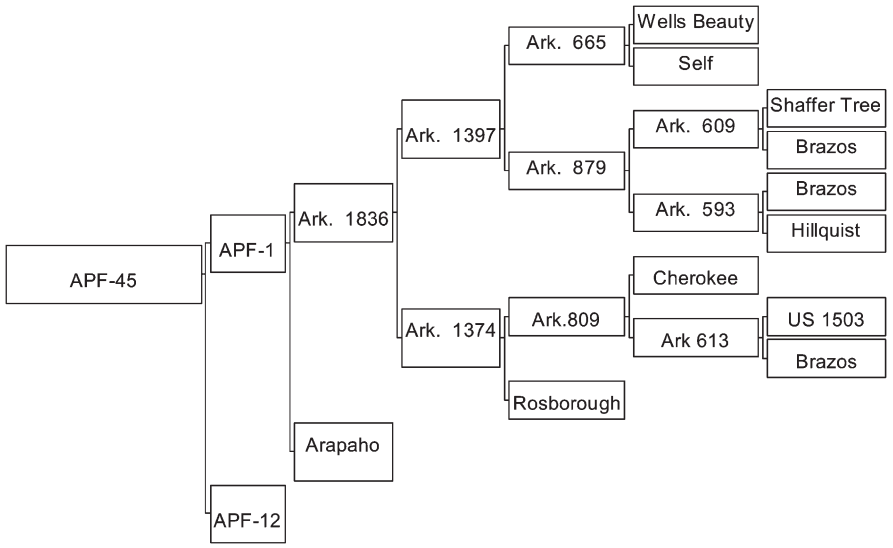

Fig. 1. Pedigree of ‘APF-45’ blackberry.

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management of these trials was the same as described previously with the exception of drip irrigation being used. Data for 10% and 50% floricane bloom and floricane first, peak, and last harvest dates along with average berry weight (25 berries measured at three harvest dates for each replication) were recorded for 2008–2009 in the 2007-established trial. For the 2004 and 2005 replicated trials, yield and berry weight were recorded. Data for replicated trials, with the exception of the data for 'APF-45' and 'APF-12' for the 2004–2005 trials, were analyzed for each year separately as a randomized complete block by the GLM procedure of SAS (SAS Institute Inc., Cary, NC).

Table 1. Floricane yield and berry weight of two primocane fruiting and two floricane-fruiting blackberry cultivars followed by primocane yield and berry weight (average weight of 25 berries measured three times each year) in a replicated trial at the University of Arkansas Fruit Research Station, Clarksville, established in 2007.

	Yield (kg·ha^{-1})		Wt/berry (g)	
Cultivar	2008	2009	2008	2009
Floricane				
APF-45	13,121 a[z]	4,194 a	6.1 b	4.7 b
APF-12	6,073 a	3,759 a	4.6 c	3.5 c
Ouachita	8,786 a	4,012 a	5.8 b	4.7 b
Natchez	14,113 a	5,548 a	7.9 a	6.2 a
Primocane				
APF-45	986 a	1,565 a	4.3 a	5.1 a
APF-12	84.1 b	146 b	3.2 b	3.3 b

[z]Mean separation within columns by *t* test ($P \leq 0.05$).

Table 2. Primocane yield and berry weight (average weight of 25 berries measured three times each year) of two primocane-fruiting blackberry cultivars for 2007 in replicated plantings established at the University of Arkansas Fruit Research Station, Clarksville.[z]

Cultivar	Yield (kg·ha^{-1})	Wt/berry (g)
APF-12	1965	4.0
APF-45	5071	5.2

[z]Data are means of four replications for 'APF-12' and two replications of 'APF-45' that were in adjacent rows, not a single planting (no mean separation provided as a result of not an appropriate design for analysis). 'APF-12' plants were planted in 2004 and 'APF-45' in 2005, and all plants were fully mature at the time of data collection.

Fig. 2. Primocane fruits of 'APF-45' in California (photograph provided by Ellen Thompson).

Postharvest evaluations were done on floricane fruits for 'APF-45' and several other cultivars for 2007 to 2010 for fruit from Clarksville. The procedures used were developed over a multiyear period in the 1990s where various measurements were taken to develop a system for genotype evaluation for potential shipping. Dry, shiny black berries (not treated with preharvest fungicides) were harvested in the morning into hinged, clear, vented, polyethylene 260-g clamshell containers (Century Corrugated Container, Kilgore, TX). Each clamshell contained on average 20 berries. Two clamshells were gathered from each genotype at two consecutive harvest dates (resulting in four replications). The berries were then stored at 5 °C, 80% relative humidity for 7 d. Subjective evaluations were made for firmness, presence or absence of visible mold, leak, or reddening. Each berry was removed from the container, determined to be firm (1) to falling apart (5) by using finger pressure between thumb and forefinger, and placed in rows for each firmness rating. Percent soft berries were those in the 4 and 5 rating categories. Each berry was rolled gently on a white paper towel and counted as leaky if juice spots appeared. For reddening, three or more berry drupelets had to be red to count as visible reddening. All ratings were converted to percentages based on the total number of fruit in the clamshell. The variables of percent berries decayed, with leakage, and soft were used in a calculation for marketability. The marketability value was calculated as: 100 – {sum [% decayed + % soft (4- and 5-rated berries) + % leaky]/3}. A minimum score of 85 was desired for a genotype to be considered likely acceptable for shipping based on the variables measured.

Evaluation of 20 plants of 'APF-45' along with 'APF-8' and 'APF-12' was also done in Watsonville, CA (lat. 36°54′37″ N; long. 121°45′20″ W; USDA hardiness zone 9) with primocane and floricane fruiting data (estimated yields determined and average berry weight for 25 berries measured) in 2008 on plants established in 2007. Primocane management treatments applied in this planting included: 1) double crop = floricanes (summer) + primocanes (fall) cropped and tipped at 1 m; 2) double-tip = main cane and subsequent branches tipped at ≈50 cm; and 3) delayed double-tip = primocanes pruned to ground once after reaching 50 cm and canes that regrew were double-tipped. An additional test plot was established at Aurora, OR (lat. 45°13′51″ N; long. 122°45′21″ W; USDA hardiness zone 8) at the North Willamette Research and Extension Center of Oregon State University in 2005. Primocanes were tipped at ≈1 m in midsummer in this trial. Primocane crop only was harvested from this plot. Data for harvest period, yield per plant, and average berry weight were collected from this single plot in 2006 to 2008.

Plant yield. Floricane yields of 'APF-45' were comparable to 'Natchez' and other cultivars in the 2007 replicated planting for 2008 and 2009 (Table 1). Substantial plot-to-plot variation was found in this planting, leading to non-significance among rather

Table 3. Plant and fruit characteristics of five blackberry cultivars at the University of Arkansas Fruit Research Station, Clarksville.

	Cultivar				
Characteristic	APF-45	APF-8	APF-12	Ouachita	Natchez
Floricane bloom date[z]					
10% bloom	28 Apr. (1.5)	—	28 Apr. (1.6)	3 May (0.5)	30 Apr. (0.9)
50% bloom	4 May (3.4)	—	5 May (3.5)	8 May (2.7)	4 May (4.2)
Floricane harvest date[z]					
First	10 June (0.7)	—	8 June (2.1)	13 June (0.0)	5 June (0.0)
Peak	24 June (2.1)	—	19 June (5.7)	30 June (0.7)	20 June (4.2)
Last	13 July (5.7)	—	17 July (13.4)	19 July (2.1)	13 July (5.7)
Primocane first bloom date[y]	30 June	16 June	13 June	—	—
Primocane first ripe fruit date[y]	8 Aug.	18 July	15 July	—	—
Fruit[xw]					
Firmness	8.1 (0.4)	6.8 (0.5)[v]	6.6 (0.5)	8.1 (0.4)	7.7 (0.5)[u]
Flavor	7.7 (1.0)	6.8 (0.5)[v]	6.4 (0.5)	8.1 (0.4)	7.5 (0.6)[u]
Soluble solids (%)[ts]	9.6 (0.5)	8.2 (0.6)	8.8 (1.1)	10.5 (1.7)	9.2 (1.1)
Plant[xw]					
Vigor	7.4 (0.5)	6.8 (1.0)[t]	7.6 (0.5)	7.0 (0.0)	6.8 (0.4)[u]
Health	7.4 (0.5)	7.3 (1.2)[t]	7.7 (0.5)	7.7 (0.8)	7.3 (0.5)[u]
Erectness	8.9 (0.4)	7.3 (0.5)[t]	7.6 (0.8)	8.3 (0.5)	6.8 (0.8)[u]

[z]Means of data collected in 2008 and 2009 from the 2007-established replicated plots with (SD).
[y]Means of 5 years, 2004 to 2008, with data collected from the observational plots.
[x]Means of 7 years, 2004 to 2010, with data collected from the observational plots with (SD).
[w]Rating scale of 1 to 10 where 10 = best.
[v]Data from years 2004–2006 and 2009–2010; 2007 and 2008 data missing.
[u]Data from years 2004–2010 with 2008 data missing.
[t]Data from years 2004–2010 with 2007 data missing.
[s]Soluble solids measured on a 25-fruit sample from observational plots harvested once during the floricane-fruiting season.

large mean differences in the data. After floricane harvest in 2008, raspberry crown borers, *Pennisetia marginata* (Harris), were discovered in the crowns of the plants, and the damage to plant crowns likely contributed to the uneven performance among replications and overall lower yields in 2009. These plants were established in 2007, and no primocane fruits were produced in the year of planting. It is noteworthy that the floricane crop of 'APF-45' was so substantial, particularly for having been planted only 1 year, and was comparable to the other cultivars in the second fruiting year. This indicates good potential for floricane cropping, particularly in the first fruiting year (when no primocane fruits are produced the summer/fall prior). Primocane yields were substantially lower than floricane yields for both 'APF-45' and 'APF-12'. 'APF-45' was higher in primocane yield than 'APF-12' in both the 2004–2005 and 2007 plantings (Tables 1 and 2). As previously reported by Clark et al. (2005), summer heat during primocane bloom and fruit development in Arkansas reduced fruit set compared with more moderate summer temperature locations. 'APF-45' shows some improvement in primocane yield over 'APF-12' based on our trials in Arkansas.

Yield data from the California trial indicated substantial promise for 'APF-45' because it was higher-yielding on an estimated basis than 'APF-12' and 'APF-8' (data not shown). 'APF-45' had higher estimated yields for double crop (flori- and primocane harvests) and double-tip cane treatments, whereas it was lower for the delayed double-tip treatment, all compared with 'APF-12' and 'APF-8'. This site has very moderate temperatures, usually with midday highs from 22 to 25 °C in August, for example, much lower than that experienced in Arkansas. The moderate temperatures allowed for much better expression of the primocane-fruiting trait and thus higher yield potential. In Oregon, yields on a kg/plant basis for the 2005-established plants for primocanes only were 0.2, 1.8, and 4.4 for 2006 to 2008, respectively (data not shown). Calculated on a larger scale, the 4.4 kg/plant yield equaled over 12,000 $kg \cdot ha^{-1}$ based on 2,800 plants/ha (a commercial planting density).

Berry characteristics. Average floricane berry weight of 'APF-45' was 5 to 6 g in the 2007 replicated trial (Table 1). It had comparable weight to 'Ouachita', larger than 'APF-12', but smaller than 'Natchez'. For primocane berries, weight in Arkansas was substantially less than that for floricanes, 4 to 5 g or near that (Tables 1 and 2).Weight for 'APF-45' was greater than that for 'APF-12', however. In California, primocane berry weight was observed to be higher than that found in Arkansas, just over 7 g/berry, and was similar to 'APF-12' and 'APF-8' (data not shown) (Fig. 2). In Oregon, primocane berry weight for 'APF-45' averaged 8.9 g for 2006 to 2008 (data not shown).

Fruit of 'APF-45' is elongated to blocky and attractive with a glossy, black finish. Fruit shape varies on primocanes and can be reduced in glossiness and color as a result of heat in Arkansas but is uniform in more suitable environments (J.R. Clark, personal observation). Soluble solids concentration for floricane fruits over 7 years averaged 9.6% for 'APF-45', 8.2% for 'APF-8', and 8.8% for 'APF-12' (Table 3). Soluble solids values from replicated plots for floricane fruits were slight higher than 10% at Clarksville for 'APF-45' (data not shown). For primocane fruits, 'APF-45' soluble solids were up to 12% at Clarksville (data not shown). Flavor ratings for 'APF-45'averaged 7.7, higher than the averages for 'APF-8' and 'APF-12' and comparable to 'Ouachita' (Table 3). Field firmness ratings averaged 8.1 for 'APF-45' and 'Ouachita' and were higher than those for 'Natchez', 'APF-12', and 'APF-8'.

Postharvest performance. Postharvest evaluations for floricane fruits at Clarksville indicated excellent performance for 'APF-45' (Table 4). For all years, marketability values were 85 or above for 'APF-45', indicating very good shipping potential. 'APF-45' was comparable to the industry standard shipping cultivar Ouachita for marketability in all years of evaluation. 'APF-45' was statistically similar to 'Tupy' in 2008 but better than 'Tupy' in 2009 and 2010 for marketability. 'APF-45' was superior to 'APF-12' for marketability. Reddening of 'APF-45' during storage was low, ranging from 0% to 25.3%. Leakage of berries was also low, from 7.5 to 29.9%, similar to 'Ouachita' for all but 2007 when 'Ouachita' performed better. Decay was always low for 'APF-45'. The percentage of berries rated soft was low in all years except 2007 for 'APF-45'. In harvest periods for each year, rainfall occurred. Rainfall within 4 d of harvest negatively impacts postharvest storage performance (Perkins-Veazie and Clark, 2005). The 2009 harvest season was particularly wet, with rainfall occurring within 4 d of most harvest dates. These data provide the basis for the recommendation for production of 'APF-45' for shipping, unlike 'APF-12' and 'APF-8', which were recommended only for home garden or local use as a result of concerns in postharvest handling potential (as a result of softness and reddening).

Bloom data. Floricane bloom dates for 'APF-45' were the same or near that for 'APF-12' and 'Natchez' and slightly earlier than for 'Ouachita' (Table 3). Floricane first

Table 4. Postharvest evaluations of 'APF-45' blackberries from 2007 to 2010 collected at the University of Arkansas Fruit Research Station, Clarksville, compared with named cultivars (7 d in cold storage at ≈5 °C).

Cultivar	Marketability[z]	Red (%)[y]	Leak (%)[x]	Decay (%)[w]	Soft (%)[v]
		2007			
Natchez	80.5 b[u]	29.4 a	12.5 b	0.0 a	29.7 ab
APF-45	85.8 ab	2.8 b	14.9 b	0.0 a	39.6 b
Apache	88.3 ab	0.0 b	16.0 b	1.6 a	24.0 a
Ouachita	90.5 a	4.5 b	5.5 a	1.6 a	22.0 a
		2008			
Natchez	91.8 a	66.6 ab	12.6 a	1.4 a	10.6 a
APF-45	85.6 ab	25.3 bc	7.5 a	0.9 a	9.6 a
Apache	80.8 ab	4.7 c	21.3 ab	10.6 b	21.1 ab
Arapaho	80.0 ab	6.1 c	26.8 ab	4.3 ab	22.9 ab
Ouachita	76.8 ab	22.8 bc	15.5 a	11.5 b	19.9 ab
Tupy	64.3 b	35.1 abc	39.7 bc	1.8 a	30.7 b
APF-12	33.3 c	75.3 a	56.0 c	11.0 b	57.7 c
		2009			
Natchez	89.3 a	14.8 ab	14.7 a	1.3 a	12.8 a
APF-45	89.0 a	4.8 b	29.9 ab	3.4 a	5.7 a
Apache	72.4 bc	0.0 b	68.8 c	18.2 bc	23.3 a
Arapaho	80.2 ab	0.0 b	56.4 c	0.0 a	22.9 a
Ouachita	88.8 a	0.0 b	35.0 ab	3.5 a	6.3 a
Tupy	65.4 c	12.0 ab	64.0 c	19.6 c	43.0 b
APF-12	72.3 bc	23.3 a	51.5 bc	11.9 ab	24.3 b
		2010			
Natchez	85.3 a	5.03 a	27.7 a	0.0 a	16.33 bc
APF-45	93.5 a	0.0 a	19.9 a	0.0 a	0.0 a
Arapaho	87.0 a	0.0 a	33.8 a	0.0a	5.3 ab
Ouachita	92.0 a	0.0 a	20.4 a	1.6 a	2.5 a
Tupy	71.3 b	5.2 a	56.3 b	3.1 a	26.0 c
APF-8	86.5 a	6.8 a	35.0 a	2.9 a	3.0 a

[z]Percent marketability ratings are used as an indicator of performance after 7 d in the cooler. Percent marketability is calculated as: 100 – {sum [% decayed + % soft (4- and 5-rated berries) + % leaky]/3}. A minimum of 85 is desired. Marketability is calculated using the per replication data for decayed, soft, and leaky berries, not the mean values presented above; this can result in differences between marketability presented and what would be calculated using the mean values presented above in the formula.

[y]The berries were rated on a yes/no scale for presence of red drupelets in clusters of three or more.

[x]The berries were rated on a yes/no scale for presence of leakiness.

[w]The berries were rated on a yes/no scale for presence of decay.

[v]The berries were rated on a 1–5 scale for softness, where 1 = firm and 5 = collapsed berry, very leaky. Means represent berries that scored a 4 or 5.

[u]Means followed by the same letter are not significantly different ($P > 0.05$) by *t* test.

Fig. 3. 'APF-45' with fruits on primocane, Clarksville, AR.

harvest date for 'APF-45' was 10 June, 2 d after 'APF-12', 5 d after 'Natchez', and 3 d before 'Ouachita' (Table 3). Peak and last harvest dates had similar trends.

Primocane first bloom date for 'APF-45' was ≈2 weeks later than that for 'APF-8' and 'APF-12' (Table 3). Primocane bloom was observed to continue until frost in some years on 'APF-45' at Clarksville, although the amount of bloom was reduced in August until mid-September as a result of high temperatures (data not shown). In most years, flowers increased in number in late September.

Maturity data. Primocane first ripe fruit date averaged 8 Aug. for 'APF-45' at Clarksville, 2 to 3 weeks later than that for 'APF-12' and 'APF-8' (Table 3; Fig. 3). This is of particular importance in more northern areas of the United States in that late-ripening fruit may be frost-damaged in the upper Midwest or similar climates. Fruiting continued until frost at Clarksville although showed a period of low production in August, then usually resumed berry production in late September and October (data not shown). In California, primocane harvest date was 20 Aug. on double-tipped canes that fruited only on primocanes and 19 Sept. on double-cropped plants (data not shown). Harvest of 'APF-45' was substantially later than 'APF-12' and 'APF-8', ≈1 month later on average. Harvest continued until early December. In Oregon, harvest extended from 13 Sept. until 11 Oct. when fall rains adversely affected fruit quality (data not shown). Use of an artificial environment such as high tunnels may extend the fall fruiting season in Oregon and subsequent yield potential for 'APF-45'.

Plant characteristics. Canes of 'APF-45' are erect with erectness ratings averaging 8.9 compared with 6.8 to 8.3 for the comparison cultivars (Table 3). Vigor rating of 'APF-45' (7.4) was within the range of the comparison cultivars (Table 3). Average health rating for 'APF-45' was 7.4 indicating good health that was consistent from year to year (Table 3). No orange rust [caused by *Gymnoconia nitens* (Shwein.) F. Kern & H.W. Thurston] was observed on 'APF-45' in any evaluations, although infected plants were seen within 30 to 50 m of data collection plots in each year of evaluation. 'APF-45' showed rare instances of anthracnose on berries in the selection observation planting in evaluations in which a single spray of lime sulfur was applied. Reaction of 'APF-45' to rosette/double blossom [*Cercosporella rubi* (Wint.) Plakidas] has not been conducted because this disease did not occur at any of the test sites.

'APF-45' broadens the opportunities to produce blackberries. The unique primocane-fruiting habit has the potential to change blackberry production in many environments, and the enhanced postharvest handling potential should allow production for the commercial shipping market. Production should be important for the late-season (fall) period when blackberries are usually in limited supply. 'APF-45' is recommended for commercial trial to determine overall adaptation and use in diverse climates.

Availability

An application for a U.S. plant patent has been filed for 'APF-45'. Nurseries are licensed in the United States and other countries for propagation; a list of these can be attained from John R. Clark (jrclark@uark.edu).

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