Journal of the American Pomological Society 61(1):3-13 2007

Cultural Methods for Beach Plum (*Prunus maritima*) Fruit Production

RICHARD H. UVA AND THOMAS H. WHITLOW[1]

Abstract

Beach plum (*Prunus maritima* Marsh.) is a shrub native to Atlantic coastal sand dunes from Maine to Maryland where it is subject to drought, nutrient and salt stress. Traditionally, beach plum fruit has been collected from the wild to make preserves, an activity that endures as a cultural tradition and cottage industry. Currently, the supply of fruit from wild stands does not meet the market's demand; hence, beach plum shows promise as a new crop for growers in the Northeast U.S. In this report, we present results of a factorial experiment evaluating the effects of irrigation, mulch, and fertilizer on growth and yield of wild collected seed-grown beach plum. Growth and yield were greater in fertilized treatments and within fertilizer regime; irrigation and mulch did not increase growth or yield. Yield component analysis indicated that branches per plant, buds/branch, flowers/bud, fruit set, and diameter/fruit all had significant positive direct effects on yield (dry weight). When two seed sources were compared, precocity and the significance and magnitude of yield components differed. Buds/branch and fruit set had the strongest significant positive effects on yield, indicating that these may be traits to select for either through genetic or cultural manipulation.

Beach plum (*Prunus maritima* Marsh.) is one of several shrubby plums native to North America. It produces small, distinctively flavored fruit that is collected from the wild for jam production and is arguably the best-known wild plum today. The earliest written account was by John de Verrazano, a Florentine voyager, who recorded "damson trees" in 1524 in the vicinity of what today is southern New York (30). Coastal place names like Plum Island in both New York and Massachusetts, and Prime Hook, a barrier beach in Delaware derived from the Dutch settlers' *Pruime Hoek*, literally, Plum Point, bear witness to its early recognition as a source of fruit. Today, coastal residents and vacationers prize beach plum jam and jelly, which command premium prices at farm stands and specialty markets.

Despite its popularity, beach plum has a curiously spotty horticultural history. In the 1890s Luther Burbank crossed improved beach plum cultivars with hybrid Japanese plums and obtained what he called the "Giant Maritima" but it was never commercialized due to poor handling characteristics (7) and apparently no longer exists. From the late 1930s to the mid 1950s, a group of fruit gatherers on Cape Cod formed the Cape Cod Beach Plum Growers' Association but they apparently planted few orchards and their interest waned for lack of horticultural information and unreliable yield from native stands (15). This experience, and the fact that today nearly all harvested fruit is collected from wild stands, led to the peculiar conventional wisdom that beach plum cannot be cultivated, and could be grown only on sand, and in close proximity to the ocean.

Selections for fruit and conservation use collected at the Arnold Arboretum and other public gardens in the 1940s are today relatively unknown to the nursery trade, meaningless to collection curators, and in jeopardy of being lost. Bare-root and containerized landscape plants are available from several nurseries, but these are largely wild-type seedlings. The Cape May Plant Materials Center (NRCS) has released a selection of beach plum known as 'Ocean View' for dune stabilization and is distributed as open pollinated seed to nurs-

[1] Postdoctoral Associate and Associate Professor (corresponding author) respectively, Department of Horticulture, Cornell University, 134A Plant Science Building, Ithaca, NY 14853

erymen. Bare root seedlings are available for similar purposes from a handful of other suppliers. A small germplasm collection was established at the Rutgers Tree Fruit Research and Extension Center in 1988 but there have been no published reports on growth habit, yield and cultural requirements that might inspire a grower to plant beach plum. Recent horticultural research has focused exclusively on the species as a potential source of salt tolerant rootstocks for commercial stone fruits (25).

Given this record, one might conclude that in today's competitive global market for fruit, beach plum warrants little horticultural attention. However, several factors suggest that this is the time for a systematic study of beach plum as a fruit crop. First, it naturally occurs on sandy, excessively drained, nutrient poor sites, strongly suggesting an untapped potential as a low input crop for marginal land. Second, the market for many commodity crops has such low margin that growers struggle to stay profitable, especially in the urbanized Northeastern US. A recent report (12) advises that the future of agriculture in the northeast lies in high value, niche market crops, especially those with underserved regional markets and the potential for value added processing. This profile matches beach plum perfectly. Third, current demand for this fruit exceeds supply by a large margin, due in no small degree to the dwindling number of accessible natural stands and collectors willing to pick. An unpublished 1997 market survey of merchants and condiment producers conducted by Cape Cod Cooperative Extension estimated that the demand by the tourist trade alone was 10,000 pounds (4536 kg) annually and speculates that with marketing, it "could exceed hundreds of thousands of pounds annually." Orchard production could meet this demand, yet with beach plum's troublesome reputation, even experienced growers are understandably hesitant to plant an orchard without rudimentary horticultural information for guidance.

In this paper we report the results of a five-year cultural trial of beach plum to determine its growth and yield responses to irrigation, fertilizer and mulch during orchard establishment. We hypothesized that in terms of both growth and yield responses, main treatment effects would be ranked Irrigation > Fertilization = Mulch = Control. We also hypothesized that satisfactory yield would be possible from non-treated controls.

As commercial development of this crop proceeds, criteria for making selections and developing pruning standards based on plant structure will need to be developed. Yield component analysis has been used on other woody fruit crops to identify characteristics that were strongly associated with yield and that could be further enhanced by breeding (17, 27). Yield component analysis can also inform decisions on cultural management in the areas of nutrient inputs (3), irrigation (22), and pruning (5, 21). We hypothesized that yield components would vary by seed source. We undertook an analysis with the goal of eventually developing an ideotype—a hypothetical plant described in terms of traits that are thought to enhance genetic yield potential (24).

Materials and Methods

Site description. Coonamessett Farm in East Falmouth, MA (N41°37'02", W70°34'33") was the location for the experimental orchard. The orchard is situated nominally on a Merrimac sandy loam (sandy, mixed, mesic Typic Dystrochrept), which recently supported an oak-pine forest, but because it has been mined for sand and gravel, only subsoil remained. Prior to planting, the soil had a pH of 4.9 with 2.6% organic matter. The combination of location, poor site conditions and the entrepreneurial business strategy of the farm made it an ideal location for the test plots.

Planting stock. Seed was collected from two maternal plants growing in native stands in fall, 1995. Source 1, from East Sandwich, MA has an upright growth habit and was chosen because it has the reputation of being a reliable bearer among local pickers. Source 0, from Barnstable, MA has a lower, spreading habit and bore a heavy fruit load.

Seed were cleaned of pulp and stratified in moist peat moss at 4ºC for five months, then planted into 1:1:1 by volume peat: Perlite: soil in long cells (656 ml, D40 Deepots™) and maintained in a greenhouse at Cornell University during their first growing season. In the fall, plants were allowed to go dormant outdoors then over-wintered in a 4ºC cooler. In March 1997, one-year-old seedlings were planted at Coonamessett on 0.9 m centers in rows 3 m apart.

Experimental and planting design. The experiment was a complete 3-way factorial, replicated five times. The site had been excavated for gravel, leaving a gradient in soil texture and presumably water holding capacity across the planting area. Five incomplete blocks controlled for this variation. The incomplete block design made most efficient use of the available plants and space. Treatments were randomly assigned to plots containing four plants: one individual from each of the two maternal sources bounded by an edge plant on either side. Factors included mulch, irrigation, fertilization and control, yielding eight treatment combinations. Mulching consisted of 10 cm of coarse oak/pine woodchips applied to selected plots at planting and again in spring, 2001. Irrigation consisted of weekly applications of 2.5 cm of water May-October via micro sprinklers (Micro-quick®N-05 E, Rainbird Agriproducts, Glandora, CA). Fertilizer treatments were based on soil tests and followed recommendations for orchard fertility (29). The fertilized plots received 155 kg P/ha and 8965 kg dolomitic lime/ha the fall before planting followed by annual spring applications of 67 kg N /ha (calcium nitrate), 99 kg K/ha and 3362 kg dolomitic lime/ha except in 2001 when N was applied at 90 kg/ha and lime at 3922 kg/ha. Zn, B and Cu were applied in foliar sprays from 1998 through 2001. In the fall before planting, fertilizer was broadcast on the exposed soil of individual plots with a hand held centrifugal spreader. The same application method was used in subsequent springs except that it had to be applied over the mulch in the mulched treatments. Alleys were seeded with a fescue-ryegrass mix (Cape Cod Species Mix, Lofts Seed Inc., Winston-Salem, NC) and mowed as needed. In-row strips were hand weeded to maintain a 1.5 m weed free zone. Pest control followed recommendations for commercial plums (16).

Growth. Trunk diameters, 5 cm above ground level, were measured after each growing season. Growth analysis was carried out using the relative production rate (RPR):

$$RPR=(\ln (y_i/y_{i-1}))/t_2-t_1$$

where ln is the natural log, y_i is current annual increment, y_{i-1} is the previous annual increment and t_2-t_1 is the time between measurements (6).

Yield. Annual yield was measured as fruit fresh weight harvested in late August each year. Soil and foliar nutrient samples were collected in early August each year. Soil samples were collected between trees with a bucket auger and separated into 0-20 cm and 20-40 cm depth fractions for analysis. Nutrients were extracted by the Nutrient Analysis Lab at Cornell University with a Morgan's solution (10% sodium acetate in 3% acetic acid buffered to pH 4.8, using a 1:5 v/v, soil: solution ratio) and determined by standard atomic absorption and colorimetric methods. Soil pH was determined on a 1:1 soil: water suspension. Mature leaves were collected in August from the current season's terminals from the outer edge of the canopy, washed in distilled water and analyzed for nitrogen by micro Kjeldahl. Other elements were extracted by dry ashing and analyzed by inductively coupled argon-plasma atomic emission spectrometry (975 Plasma Atomcomp with ICAP 61 Update (Jarrell-Ash, Franklin, MA). Statistical analysis was carried out using mixed model procedures (20) in SAS version 6.12 (SAS Institute Inc. Cary, NC).

Yield Component Analysis. For the yield component analysis conducted in 1999, data were combined across factors. Yield components were configured in the following causal relationship (Figure 1). Path analysis (19) was used to evaluate yield components. The natural log of component variables was taken

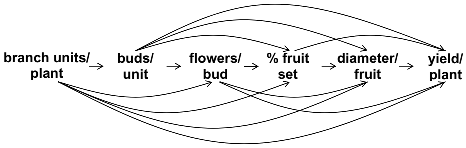

Figure 1. Path diagram illustrating all of the possible causal relationships of predictors on criterion variables.

and the data transformed into standard deviates by subtracting the means and dividing by the standard deviation. Mixed linear models (Proc Mixed, SAS Institute, Cary, NC) were used to generate standard partial regression coefficients the magnitudes of which can be compared directly to show the relative standardized effects of several independent variables on the same dependent variable (28). The significance of path coefficients was determined with an F test. In the analysis no block effects were found by the likelihood ratio statistic, therefore the blocks were dropped from the analysis.

Beach plum grows with long shoots at the distal ends of one-year-old shoots and short shoots toward the base. Spur shoots are uncommon and flowers form on one-year-old wood. Plants were sampled as branching units consisting of two years' wood growth with associated buds (Figure 2). Rather than counting on a per limb or canopy area basis, the

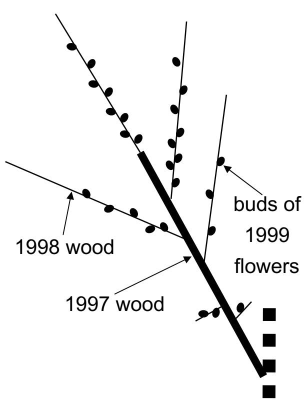

Figure 2. Illustration of a branch unit and the typical branching pattern of *P. maritima.* Bud counts from 1-year-old wood were tallied per branching unit.

branching unit structure was chosen because it is the basic iterative unit and can be scaled up for comparison to older plants. On May 9, 1999, as buds enlarged before bloom, all branch units per plant were counted. Stratified samples of three branch units per plant from 31 flowering plants were used in the yield component analysis. The second unit from the top, the middle unit on the plant and the second unit from the bottom were chosen for analysis. At bloom, flower number, bud number, and flowers/bud were counted for each selected branch unit and averaged for each plant. Yield (grams dry weight) per plant and diameter (mm) of the ripe fruit were measured during August of the same growing season.

Results

Soil. Soil nutrient concentrations at the 0-20 cm depth varied by fertilizer regime and by year (Table 1). Over 5 years, applications of dolomitic lime raised pH to 6.8, and calcium and magnesium levels substantially, compared to unfertilized plots. Nutrient concentrations deeper in the soil profile (20-40 cm) did not respond to fertilization (data not shown). Annual fertilizer applications increased soil nutrient concentration with the exception of N, which was below detection as expected in very sandy soils. Pre-plant incorporation increased phosphorus concentration and the effect of this single application persisted for the duration of the experiment as is common in orchard establishment (29). Annual applications of K resulted in an increase over unfertilized treatments, and there was evidence of increase in soil K over the experimental time frame.

Growth and Yield. We found no significant interactions among factors, hence we will address main effects. All treatment combinations that included fertilizer had consistently higher RPR than those that lacked fertilizer (Figure 3A). Contrary to our expectations, neither mulch nor irrigation had a consistent effect on RPR. In those years where differences were observed (1999 for mulch, 1998 for irrigation) the non-treated plants had higher RPR (Figure 3B and C). We will therefore focus on comparisons between fertilized and non-fertilized

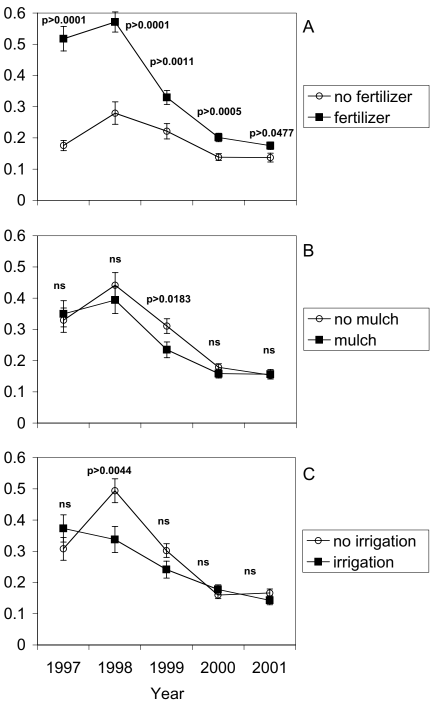

Figure 3. Effect of fertilizer (A) mulch (B) and irrigation (C) application on relative production rate by year. Bars represent standard error of the mean (n=77).

treatments for the remainder of this section. Increased growth rate led to bigger plants. Due to the incremental nature of woody plant growth, dramatic differences in trunk diameter were soon apparent (Figure 4).

Plants did not yield in year one, the year of orchard establishment. In addition to increasing RPR beginning in year 2, it is noteworthy that fertilizer increased yield precocity by 15-20%. After the first two years, fertilization increased fruit yield (Figure 5). By year 5 (2001), average yield from fertilized plants was 877 g, in comparison with only 122 g from non-fertilized plants. The highest yielding plant overall was in the fertilizer treatment with 4700 g of fruit in 2001. A biennial bearing pattern may be developing, as evidenced by decreased yield in 2000 in the fertilized plants. Fertilizer also affected fruit size. In 1999 fruit from fertilized plants averaged 1.4 mm larger in diameter (p = 0.05), while irrigation had no effect on size. Yield efficiency (kg fruit yield/cm^2 trunk area) was calculated by fertilizer treatment and was significantly higher

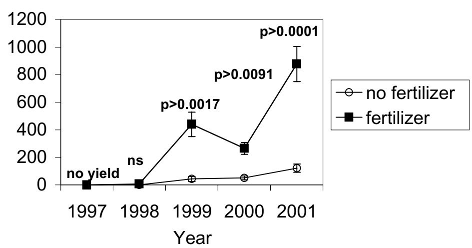

Figure 5. The effect of fertilizer on average fresh fruit weight per plant during orchard establishment with standard error of the mean within each year (n=77).

in the fertilizer treatment in years 1999 and 2001 (Table 2).

To investigate the relationships between foliar nutrition and plant performance, foliar nutrient levels were tested as predictors of growth rate and yield. Although several nutrients (N, Ca, Cu, and Mn) were predictors of growth in particular years, none was significant throughout the entire experiment and there were no suggestions of a consistent pattern (data not shown). When we compared our foliar nutrient levels to levels reported in the literature for cultivated plums (26), the observed beach plum values fell at the lower end of the range and were comparable with levels observed in natural dune populations of beach plum (Table 3).

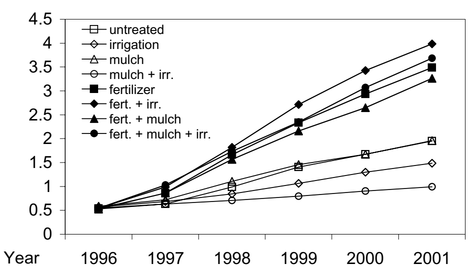

Figure 4. Mean trunk diameters by treatment over the course of the experiment.

Table 1. Average of extractable soil nutrients and pH by fertilizer treatment (0-20 cm). N is omitted because it was only rarely above the detection limits in our analysis.

Year	Nutrient (ppm) and pH	No fertilizer	Fertilizer
1997	P	0.8	1.6
	K	19.3	26.6
	Ca	94.3	148.0
	Mg	18.3	41.3
	pH	4.7	4.8
1998	P	0.9	1.6
	K	29.2	44.4
	Ca	89.9	233.4
	Mg	20.3	66.3
	pH	5.2	5.7
1999	P	0.3	1.1
	K	17.9	40.2
	Ca	101.8	228.9
	Mg	18.0	66.5
	pH	5.2	5.9
2000 (no data)			
2001	P	0.3	1.3
	K	18.8	60.1
	Ca	89.0	503.0
	Mg	20.3	117.8
	pH	5.5	6.9

Table 2. Yield efficiency (kg fruit yield/cm^2 trunk area) by fertilizer treatment and year.

Year	1997	1998	1999	2000	2001
No Fertilizer no yield	0.001	0.012	0.020	0.023	
Fertilizer	no yield	0.005	0.099	0.035	0.097
p-value		ns	0.001	ns	0.003
n		76	77	74	72

Yield Component Analysis. For yield component analysis, separate mixed linear models were developed: one for the entire planting and one for each of two seed sources. Across the entire experiment, branch units/plant, buds/unit, flowers/bud, fruit set and diameter/fruit all had significant positive direct effects on fruit dry weight ($p<0.05$, Figure 6A). Of all of the predictor variables, buds per unit had the highest path coefficient (0.72) of the model. Branch units/plant had the only significant indirect effect through diameter/fruit. The total effect of branch units/plant was 0.31. No significant negative effects were found.

When yield components were compared by seed source, the significance and magnitude within the separate models differed: source 1 had significant positive effects of buds/unit on flowers/bud and in turn flowers/bud on yield (Figure 6B). Also, in the model for seed source 1, diameter/fruit had a significant effect on yield/plant. For both models, buds/unit had the strongest effect on yield; for seed source 1 it was the strongest effect in the model whereas for source 0 the strongest effect was branch units/plant on diameter/fruit. Twice as many plants from seed source 1 as from seed source 0 fruited in year three indicating greater precocity. Means of the yield components for each seed source are presented in Table 4. Only branch units/plant and flowers/bud differed significantly between the seed sources, with source 0 higher for both. Of the two seed sources tested, 0 had a higher mean RGR than seed source 1, in 3 out of 5 seasons (Figure 7A). Yield was not significantly different between the seed sources (Figure 7B). Table 5 shows the yield of the five most productive plants along with the cumulative yield efficiency per plant.

Discussion

Growth rates differed between fertilized and unfertilized treatments, especially during the first two years of our experiment (Figure 3). The rates seem to be converging, yet the plant sizes were much different. This pattern can be attributed to an initial growth surge in young fertilized plants, also to greater biomass allocation to fruit vs. shoot biomass in the fertilized treatments as indicated by a significantly higher yield efficiency in 1999 and 2001 (Table 2). Early fertilization had two important benefits. First, because the carryover effect on plant size is cumulative, at the end of year 1 fertilized plants were larger and became proportionately larger than unfertilized plants in subsequent years, with concomitant yield increases. Second, fertilization led to precocity. Whereas only 10% of the non-fertilized plants bore fruit in 1998, 30% of the fertilized plants fruited that year. The difference in RPR between fertilized and unfertilized plants decreased over the duration of the experiment but whether fertilizer can be eliminated in later years without sacrificing yield remains to be seen.

Mulch and irrigation did not have a positive effect on growth. Irrigation either reduced growth as in 1998, or had no effect. In 1998, precipitation was 38% more than the 60-year average for this region; irrigation may have resulted in soil being saturated for longer periods to the detriment of growth. This seems unlikely, however, given the sandy soil. Another potential effect could be that superfluous water leached nutrients from the root zone. Perhaps the lack of an effect from supplemental irrigation should not be surprising. The beach plum accessions used in this experiment were all collected from sandy coastal sites, typical of its native habitat (2). Seed were collected from plants growing on a Hooksan sand which are very deep, excessively drained soils on vegetated sand dunes adjacent to coastal beaches (14). Beach plum reportedly has a large, coarse taproot which does grow deeply into the soil (4). A large taproot and large root biomass are characteristic of stress tolerant plants found on infertile soils (9).

It should be noted that a separate study (25) reported that adaptations to drought in beach plum and several other *Prunus* species were found to be more closely related to shoot characteristics (specific leaf area, stomatal conductance, carbon assimilation rate) than to

Table 3. Comparison of plum mean foliar nutrient values compiled from the literature (26) with averaged fertilized and non-fertilized plants in this experiment (2001 values), and the average values of two beach plums found in the wild in Barnstable County, MA.

Element	Literature reports	Fertilized	No fertilizer	Plants in dunes
% N	2.20-2.75	2.31	1.86	2.06
% P	0.16-0.30	0.13	0.16	0.21
% K	1.80-2.80	1.33	1.46	1.71
% Ca	1.60-3.10	0.90	0.79	0.75
% Mg	0.25-0.47	0.26	0.21	0.35
B ppm	25-53	23.0	25.0	28.5
Zn ppm	22-50	14.0	11.0	17.5
Cu ppm	6-12	5.0	4.0	4.0
Mn ppm	40-140	30.0	74.0	40.5
Fe ppm	75-175	75.0	81.0	38.5

Table 4. Mean of yield components by seed source (1999). A two-sample t-test was used to compare the means (n=31).

Seed source	Branch units/ plant	Buds/ unit	Flowers/ bud	% fruit set	Diameter/ fruit	Yield/ plant (g)
1	11.6	18.7	2.6	30.9	16.0	100
0	14.7	5.7	3.0	16.3	16.3	120
p-value	0.03	ns	0.01	ns	ns	ns

Table 5. Yield (g) and cumulative yield efficiency (kg fruit yield/cm^2 trunk area) of the 5 largest producing plants over the course of the experiment.

Plant number	Seed source	Year 1997	1998	1999	2000	2001	Total yield(g)	Yield efficiency kg/cm2
162	0	0	7	2259	1822	588	4675	0.10
11	1	0	0	0	118	4700	4818	0.30
121	1	0	0	962	0	4325	5287	0.40
134	0	0	16	4889	3	1510	6418	0.26
5	1	0	2	2144	1697	2944	6787	0.40

root characteristics. However, this study did not specifically evaluate the plants' ability to acquire water by a deep root system.

Species restricted to infertile soils purportedly respond less to nutrient addition than do related plants indigenous to more-fertile soils (11). Beach plum responded strongly to fertilizer in both growth and yield, yet despite the addition of both soil and foliar applied nutrients, leaf nutrient concentrations remained below reported levels for cultivated plums, suggesting that beach plum has high nutrient use efficiency. Soil nutrient concentrations were increased by the fertilizer applications, consistent with our initiating hypothesis that fertilization would lead to higher soil nutrient concentrations, leading to higher foliar nutrient concentrations and greater yields. Our findings broadly meet this expectation, despite the fact that the observed foliar concentrations were at the lower end of the range reported for plums in cultivation. While nitrogen was not readily detectable in the soil, foliar N levels were substantially higher in the fertilized plants.

As a pioneer plant on infertile soil, beach plum resembles other stress tolerant plants as characterized by slow growth, low need to acquire nutrients, and low photosynthetic rates (10). This is similar to *Prunus pennsylvanica* L.f., a pioneer species in disturbed inland forests that has a relatively poor ability to acquire soil resources and consequently a lesser ability to compete for light (13). Significant effects contributing to plant yield come from components determined during current (% fruit set, diameter/fruit) and past (branch units/plant, buds/unit, flowers/bud) growing seasons. Buds/unit had strong direct effects on yield. Few comparable yield component studies have investigated Rosaceous species. In comparison with beach plum, flower density had only a small direct effect on yield in pear and this was at times negative (18). In a similar analysis for blueberry, buds/cane exhibited the strongest positive effect of the model on yield while it had a negative effect on fruit size (23).

A yield component study on another stone fruit, 7- and 8-year-old sour cherry (*Prunus cerasus* L.), found no significant negative path coefficient on two different cultivars (8). We observed no significant negative effects in beach plum, either, indicating that there was no compensation among components. Negative correlations among yield components are

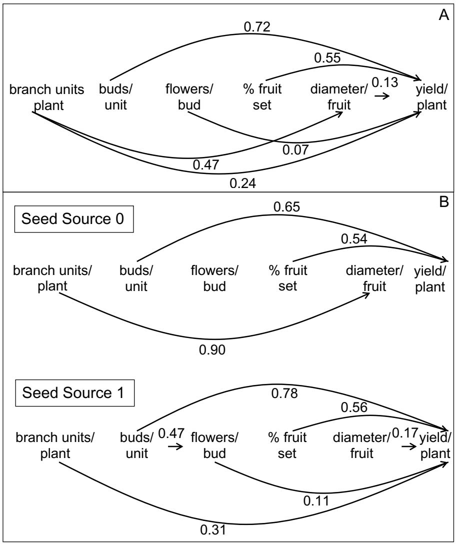

Figure 6. (A) Data combined across seed source. Values shown are path coefficients with p values < 0.05. (B) Data analyzed separately by seed source.

widespread among crop plants, particularly under various kinds of environmental stress (1). The lack of significant negative effects in beach plum may well be the result of the small plant size in our young orchard. At the time of path analysis data collection, plants were in their third year. In other fruit crops compensatory or negative effects on yield have been associated with increased canopy density (raspberry and cranberry) (17, 31), higher fruit set (grape) (5), and in response to competition from other plants (cranberry) (31). The small fruit loads on our young orchard might not induce much, if any, compensation. Re-examination when plants are larger, with heavy fruit loads is necessary to investigate this topic further.

When dealing with a new crop, growers need to know production methods and crop improvement criteria. In terms of cultural practices, several conclusions may be drawn from our study. First, we found that fertilization leads to larger, more precocious plants that yield more fruit. While this is by no means novel, it contradicts the conventional wisdom that beach plum thrives on neglect. Because we may be seeing the onset of an alternate bearing habit in some plants, we anticipate that the need to develop methods of thinning, pruning and fertilization to even out the yield. We also experienced problems with brown rot fungus (*Monilinia* spp.) and were unable to obtain satisfactory control of it with minimal applications of sulfur-based fungicides in 2000 and 2001. Better control was obtained in subsequent years using Propiconazole (Orbit). While interest has been expressed in growing beach plum organically, we suspect that extremely diligent methods for brown rot control will be necessary if weather conditions favor that pathogen.

In the future an ideotype for making selections from the wild can be developed (24). In this experiment we used half-sib seedlings from only two maternal plants growing in the wild. Despite this small and arbitrary sample, we found evidence of genetic variation in yield components that could guide selections. Ignoring fruit set, (which can be dramatically influenced by environmental factors beyond

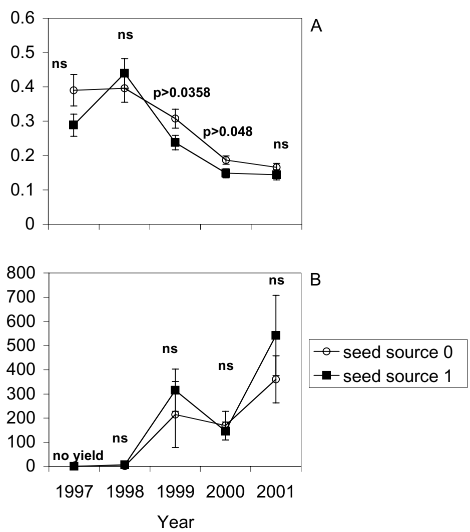

Figure 7. Plant responses from seed source 0 and 1 averaged over all treatments. (A) RPR of stem diameter by year. (B) Fresh weight by year. Bars represent standard error (n=77).

genetic control), buds/branch unit was the only variable that had a strong direct influence on yield in both sibling populations.

Because we also found differences in fruit length among individuals, fruit size will be another selection criterion. However, larger fruit may not have the desirable tartness imparted by the skin, so decisions about how fruit size should be used in a selection program must await analysis of jam qualities.

Beach plum is a stress tolerant crop that can be grown successfully on sites without irrigation, even on sandy, low-nutrient soils. Farms in the coastal Northeast are situated near the traditional market for this fruit and often have sandy uplands unsuited to other crops where beach plum could be grown. While irrigation is apparently unnecessary on these soils, we have shown that with liming and a typical orchard fertilizer regimen this wild species can be successfully cultivated with standard orchard practices for plum production. We hope that the work we report here will catalyze continued development of this crop by growers.

Acknowledgements

We thank Ronald Smolowitz for allowing us to use a portion of his farm, William Clark, and David Simser of Cape Cod Cooperative Extension for assistance in conducting field work and securing funding, Francoise Vermeylen and Walter Fedderer for statistical consultation, Warren Stiles for advice on orchard design and management, Marvin Pritts for advice on yield component analysis, and Ian Merwin for comments on the manuscript. For financial support we thank The James R. Jewett Fund of the Arnold Arboretum of Harvard University, Cornell Agroforestry Working Group, Friends of Long Island Horticulture, Landscape Plant Development Center, Massachusetts Department of Agricultural Resources Agro-Environmental Technology Program, The Sussman Environmental Internship and the Northeast Sustainable Agriculture, Research and Education Program (SARE).

Literature Cited

1. Adams, M.W. 1967. Basis of yield component compensation in crop plants with special reference to the field bean, *Phaseolus vulgaris*. Crop Sci. 7:505-510.
2. Anderson, E. and O. Ames. 1932. Botanizing from an airplane. Arnold Arboretum of Harvard University, Bulletin of popular information. Series 3 Vol. 6(nos. 10 and 11): 37-44.
3. Archibald, D.D., J.G. Strange, and D.M. Hines. 1989. Yield component responses of 'Hull Thornless' blackberry to nitrogen and mulch. HortScience 24:604-607.
4. Bailey, J.S. 1944. The beach plum in Massachusetts. Mass. State College: Amherst, MA.
5. Bowen, P.A. and W.M. Kliewer. 1990. Influence of clonal variation, pruning severity, and cane structure on yield component development in 'Cabernet Sauvingnon' grapevines. J. Amer. Soc. Hort. Sci. 115:530-534.
6. Brand, D.G., G.F. Weetman, and P. Rehsler. 1987. Growth analysis of perennial plants: the relative production rate and its yield components. Ann. Botany 59:45-53.
7. Burbank, L., 1914. Small Fruits. How Plants are Trained to Work for Man. Vol. 4. 384.
8. Chang, L.S., A.F. Iezzoni, and J.A. Flore. 1987. Yield components in 'Montmorency' and 'Meteor' sour cherry. J. Amer. Soc. Hort. Sci. 112:247-251.
9. Chapin, F.S. 1980. The mineral nutrition of wild plants. Ann. Rev. of Ecol. and Systematics 11:233-260.
10. Chapin, F.S. 1991. Integrated responses of plants to stress: a centralized system of physiological responses. BioScience 41:29-36.
11. Chapin, F.S., P.M. Vitousek, and K. Van Cleve. 1986. The nature of nutrient limitation in plant communities. Amer. Naturalist 127:48-58.
12. Cornell University. 2003. The future of American agriculture. In: CALS Connect. Cornell University: Ithaca, NY.
13. Fahey, T.J., J.J. Battles, and G.F. Wilson. 1998. Responses of early successional northern hardwood forests to changes in nutrient availability. Ecol. Monographs 68:183-212.
14. Fletcher, P.C. 1993. Soil survey of Barnstable County, Mass. Soil Conservation Service.
15. Graves, G. 1949. Looking towards beach plum cultivation. Arnoldia 9:53-64.
16. Hauschild, K.I., (ed.) 1999. Peaches, pears and plums: a production guide for Massachusetts and pest management guide for New England Growers. Univ. of Mass. Exten.: Amherst, MA.

17. Hoover, E., J. Luby, D. Bedford, and M. Pritts. 1988. Vegetative and reproductive yield components of primocane-fruiting red raspberries. J.Amer. Soc. Hort. Sci. 113:824-826.
18. Kappel, F. 1990. Yield component analysis of 'Harrow Delight,' 'Kieffer,' and 'Harvest Queen' pear. J. Amer. Soc. Hort. Sci. 115:25-29.
19. Li, C. C., 1975. Path Analysis. Pacific Grove, CA: Boxwood Press. 346.
20. Little, R.C., G.A. Milliken, W. Walter, and R.D. Wolfinger, 1996. SAS system for mixed models. Cary, NC: SAS Institute, Inc. 633.
21. Nehrbas, S.R. and M.P. Pritts. 1988. Effect of pruning system on yield components of two summer-bearing raspberry cultivars. J. Amer. Soc. Hort. Sci. 113:314-321.
22. Ostermann, J. and P. Hansen. 1998. Effects of drip-irrigation on yield components of black currants (*Ribes nigrum*). Acta Agric. Scand. 38:171-176.
23. Pritts, M.P. and J.F. Hancock. 1985. Lifetime biomass partitioning and yield component relationships in the highbush blueberry, *Vaccinium corymbosum* L. (Ericaceae). Amer. J. Bot. 72:446-452.
24. Rasmusson, D.C. 1987. An evaluation of ideotype breeding. Crop Science. 27:1140-1146.
25. Rieger, M. and M.J. Duemmel. 1992. Comparison of drought resistance among *Prunus* species from divergent habitats. Tree Physiol. 11:369-380.
26. Sanchez-Alonso, F. and M. Lachica. 1987. Seasonal trends in the elemental content of plum leaves. Commun. In. Soil Sci. Plant Anal. 18:31-43.
27. Siefker, J.H. and J.F. Hancock. 1986. Yield component interactions in cultivars of the highbush blueberry. J.Amer. Soc.Hort. Sci. 111:606-608.
28. Sokal, R.R. and F.J. Rohlf, 1981. Biometry. 2 ed. New York: Freeman and Company. 859 pp.
29. Stiles, W.C. and W.S. Reid. 1991. Orchard Nutrition Management. Cornell University Cooperative Extension: Ithaca, NY.
30. Wight, W.F. 1915. Native American species of *Prunus*. Bulletin of the U.S. Dept. of Agric. 179:1-75.
31. Yas, A.M. and G.W. Eaton. 1982. Effect of cotton-grass on the yield components of cranberry. Scientia Hort. 18:125-129.

U.S. Postal Service Statement of Ownership, Management and Circulation

Journal of the American Pomological Society is owned and published by the American Pomological Society, with publication and business offices located at: 102 Tyson Building, University Park, PA 16802. Frequency of issue: quarterly. Publication number: 211-320. Annual subscription price: $50.00. Editor: Cheryl R. Hampson, Agriculture and Agri-Food Canada, Pacific Agri-Food Research Centre, P.O. Box 5000, Summerland, BC Canada V0H 1Z0. Business manager: Robert M. Crassweller, 102 Tyson Building, University Park, PA 16802.

The average number of copies of each issue printed during the preceding 12 months was 550; total paid circulation, 392; free distribution, 0; total distribution, 392; office use and left over, 158. The actual number of copies of a single issue published nearest to filing date was 550; total distribution, 392; office use and left over, 158.

I certify that the statements made by me above are correct and complete. R.M. Crassweller, Business Manager. December 31, 2006.