Fruit Varieties Journal 47(1):38-46 1993

Evaluation of Own-rooted vs. Budded Prune (*Prunus Domestica* L.) Seedling Genotypes

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Abstract

Growth characteristics of *Prunus domestica* seedlings on their own roots were compared to the same genotypes budgrafted to vigorous, 1 year-old, commercial 'Marianna 2624' rootstock. Mean shoot growth of budded genotypes on the rootstock was substantially greater than on their own roots. Growth of seedling genotypes on their own roots was only moderately correlated with growth on the rootstock. The 10 tallest seedling genotypes generally had larger, more active (higher rates of leaf photosynthesis and leaf conductance to water vapor) leaves than the 10 shortest genotypes both on their own roots and as scions on the rootstock. There were no consistent, statistically significant differences in midday stem water potential between tall and short genotypes but short genotypes on their own roots had significantly lower midday stem water potentials than their counterparts growing as scions. Among the entire population of 54 genotypes studied, the leaves of scion grown plants had significantly higher mean leaf concentrations nitrogen and potassium, but no consistent differences in phosphorus. Growth of genotypes as seedlings was positively related to leaf nitrogen concentration but negatively related to leaf potassium concentration. There was no relationship between leaf nitrogen or potassium concentration of the same genotypes grown as scions.

Introduction

Prunus domestica L. European plum is the primary species of commercial plum and prune cultivars. It is a hexaploid species that is thought to have originated as a hybrid between *P. cerasifera* Ehrh. and *P. spinosa* L. (3) or some other combination of plum species (15). Most European plum genotypes are highly heterozygous for many characters and therefore their progeny are highly variable (18). This variability is particularly pronounced with respect to seedling size and vigor as shown in progeny being evaluated in a prune breeding project being conducted at the Kearney Agricultural Center of the University of California near Fresno, California. In the second year after planting seedling height varied from 0.1 to 2.0 meters. Similar seedling size and vigor variation has been found in *P. domestica* seedling populations in France (R. Bernhard, personal communication) and Italy (C. Fideghelli, personal communication).

With the current trend in fruit tree planting systems, large, rapidly growing commercial fruit tree genotypes are not necessarily desirable. However, rapid, uniform tree growth is desirable when evaluating seedlings in a fruit tree breeding program. There is apparently a relationship between seedling height and flowering in many fruit tree species (17). Slow growing seedlings also require intensive weed management and herbicide application is difficult to achieve without damaging the seedlings.

In some tree crops plant breeders bud-graft genotypes into mature trees in order to promote rapid growth and early flowering (11, 17). In 1987 an experiment was initiated to test the feasibility of using this method for progeny evaluation in a *P. domestica* breeding program. The primary goals of this experiment were to determine: 1) if budding onto a common rootstock would increase the growth of seedling genotypes, 2) if there was a relationship between seedling growth and growth of the same genotype budded onto a clonal rootstock and 3) if there were consistent relationships between seedling and scion growth and leaf function, water status or nutrient content that could explain growth variability.

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Materials and Methods

The seedling genotypes used in this experiment were obtained by open pollination of 3 commercial prune cultivars ('Moyer,' 'Burton,' 'Improved French') and 3 University of California *P. domestica* seedling selections (2-8-4, 10-7, 3-4) in 1985. In 1986 seedlings were planted into sandy loam soil at the Kearney Agricultural Center of the University of California. The seedling planting density was 0.75 x 3.7 meters. In the spring of 1987 fifty-four selected genotypes representing a broad range of tree vigor were budded onto clonally propagated Marianna 2624 (*P. cerasifera x P. munsoniana*; [4]) rootstocks that were transplanted from a commercial nursery in the previous winter. To conserve space in the evaluation block four to six genotypes were budded onto separate branches of each rootstock and each genotype was represented by one scion. The rootstock caliper was 1.5 cm when planted in the winter of 1987 at a plant density of 3 x 3.7 meters. Seedlings and budded trees received low volume irrigation through microsprinklers approximately every ten days throughout the growing season. Fertilizer nitrogen (-180 kg N per irrigated hectare) was applied uniformly within the research blocks through the irrigation system. Pest and weed control were achieved using standard nursery practices. Pruning was minimal in both plots. The budded trees were pruned only to eliminate competing rootstock shoots and seedlings were pruned lightly to encourage vertical upright growth of a dominant shoot in a few multi-stemmed seedlings. No pruning was performed between May and November of 1988 when growth measurements were made.

Growth Measurements. Tree height was measured in spring and fall of 1988. Seedling height attained in 1986 and 1987 was estimated from the location of terminal bud scars on the trunk in the spring of 1988.

Current season growth was measured every two weeks from May through September 1988. The three most vigorous shoots on the seedlings and scions were tagged in May and these same shoots were measured on each sampling date. While making shoot length measurements, notes were also taken on the growth status of the terminal buds. A genotype was considered to be "actively growing" when at least two of the three shoot tips were still active. In September, lateral shoots more than 10 cm long were counted on these same three shoots and the number of lateral shoots per meter of main shoot was calculated to provide a measure of the branching characteristics of the genotypes.

Leaf Measurements. At monthly intervals 10 leaves were collected from the seedling and scion trees of each genotype. Leaf area of the harvested leaves was determined with an electronic leaf are meter (L1-3000, Li-Cor Inc. Lincoln, NE). The leaves were oven-dried (75°C), weighed, ground and analyzed for nitrogen, phosphorus, and potassium. Nitrogen content was determined by modified Kjeldahl analysis as developed by Carlson (2). Phosphorus analysis was performed with an vananomolybdate reagent (10) and K was measured by flame emission spectrophotometry after extraction in 2% acetic acid.

Leaf chlorophyll content was determined in May on leaf disk samples taken from fully expanded sun exposed leaves. Chlorophyll was determined as described by Moran and Porath (12) and modified by Inskeep and Bloom (8).

Measurements of leaf conductance, photosynthesis and stem water potential were restricted to 10 of the tallest and 10 of the shortest seedling genotypes grown as seedlings and scions. At periodic intervals from May through September leaf conductance to water vapor was determined with a LiCor 1600 steady state porometer (LiCor Inc., Lincoln, NE). These measurements were made during mid-morning and/or mid-afternoon under clear skies. Three mature, exposed leaves were measured on each of the 20 subselected genotypes growing as seedlings and scions. On 3 dates (May 18, July 14, and July 20) leaf net CO_2 assimilation rate and leaf conductance to water vapor were measured on the same plants with a portable gas exchange system (LCA-2, DL-2 and Parkinson leaf cuvette; Analytical Development Corporation, Hoddeson, England).

Stem water potential measurements were limited to three measurement dates because of limited stem tissue available for measurements on the smallest genotypes. The measurements were performed with a pressure chamber (16) on lateral shoot tips, and made on clear days after water was withheld a few days more than usual so that any genotype potential differences in water status would be accentuated.

Results

Growth of the seedling population. At the beginning of the third growing season there was a large variability among the 54 seedlings growing on their own roots (Fig. 1). The shortest seedling was 15 cm tall and the tallest was 260 cm. Most were between 25 and 180 cm.

There was a statistically significant positive correlation ($r = 0.623$, $p \geq 0.01$) between the length of the central shoot after the first (1986) growing season and the increment of growth attained during the second (1987) growing season (data not shown). Similarly there was also a significant positive correlation ($r = 0.447$, $p \geq 0.01$) between the growth increments of the central leader in the second (1987) and third (1988) growing seasons (data not shown).

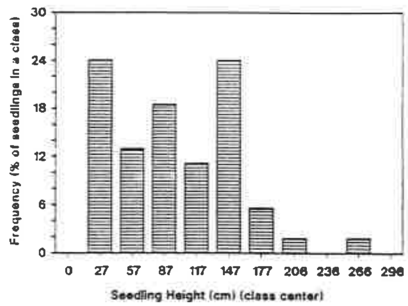

Figure 1. A frequency distribution of the *Prunus domestica* seedling population divided into 9 height classes. The range of each height class is equal to one-half the standard deviation about the mean of the total population.

Comparison of seedling and scion shoot growth

Mean shoot growth of bud-grafted seedling genotypes on Marianna 2624 was substantially greater than on their own roots. By the fall of 1988, 65% of the grafted trees had mean shoot

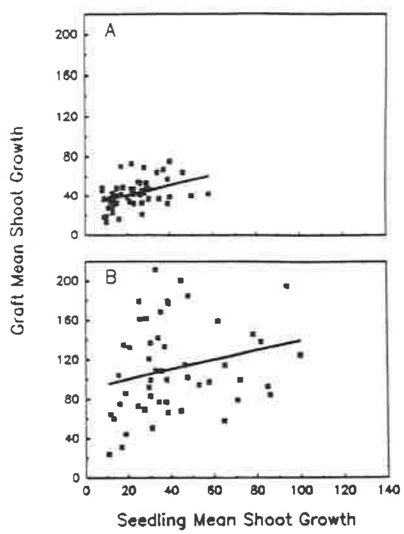

Figure 2. The correlation between mean shoot length of seedling genotypes on their own roots and the same genotypes on a Marianna 2624 rootstock on 2 May 1988 ($r = 0.398$) and 8 September 1988 ($r = 0.251$).

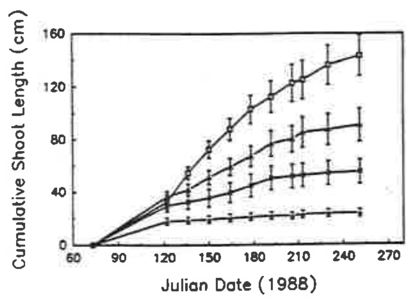

Figure 3. The seasonal pattern of mean cumulative shoot length of the 10 shortest (Δ) and tallest (□) seedling genotypes on their own roots (solid symbols) or bud-grafted onto Marianna 2624 rootstock (open symbols). Vertical bars indicate ± SE.

lengths more than double those of seedling trees and for 43% it was more than tripled. A weak correlation between tagged-shoot growth of seedling and grafted trees was evident in May, 1988 (Fig. 2a) and was maintained through the season until September, 1988 (Fig. 2b). Although these positive correlations ($r = 0.398$ and 0.251) were statistically significant ($p \geq 0.05$) there was substantial scatter in the data, particularly in September. Although substantial growth occurred on both the seedlings and the grafts between May and September 1988, the slope of the relationship between the two did not change. This indicates that the relative rate of growth of seedlings compared to grafts of the same genotype remained fairly constant through the growing season.

This same pattern is reflected in the cumulative growth of 20 selected genotypes. The 10 shortest seedlings at the beginning of the 1988 growing season maintained the lowest mean shoot growth throughout 1988 (Fig. 3). Similarly, the mean cumulative shoot growth of the 10 tallest seedlings at the beginning of the 1988 season was always greater than the short seedlings. The mean cumulative scion shoot growth was always greater than the seedling shoot growth of the same two groups of genotypes, respectively.

Not only did the grafted scions grow longer shoots than the seedlings, they also exhibited substantial more lateral branching. By September, 1988 the mean (± SE) number of lateral shoots more than 10 cm long per meter of main shoot length was significantly larger for the 54 genotypes growing as scions (5.25 ± 0.51) as compared with seedlings (1.49 ± 0.32).

Genotypes growing as scions on Marianna 2624 rootstock maintained higher mean growth rates later into the season than did seedlings growing on their own root (data not shown). Part of the reason for a higher mean growth rate of all scions compared with all seedlings is because more scions continued active growth late in the growing season than did seedlings (data not shown). More than 50% of the scions were growing on any given sampling date until mid-September. The growth of seedlings appeared to be more susceptible to growth flushes and after the first of July there were always less than 40% of the seedlings actively growing on any one sampling date.

Comparisons of leaf characteristics

The mean area per leaf of all 54 seedlings, collectively, remained constant from May through the middle of July while the mean leaf mass per unit leaf area increased substantially over the same period (Table 1). Conversely, the mean area per leaf of the same genotypes on the Marianna rootstock increased 28% but mean leaf mass per unit area remained constant.

Within the population of seedlings the 10 tallest seedlings had significantly greater mean area per leaf than the 10 shortest seedlings already in early May and these difference increased with time (Table 2). Although the same 10 tall and small genotypes grafted on Marianna rootstock started the season with similar mean area per leaf in

Table 1. A comparison of mean (± se) leaf size (cm²) and leaf mass per unit area (mg·cm⁻²) between all 54 seedling genotypes growing on their own roots and on Marianna 2624 rootstock at 3 sampling dates.

Date	Leaf Size (cm²)		Leaf Mass per Unit Area (mg·cm⁻²)	
	Seedlings	Scions	Seedlings	Scions
May 10	8.94 ± 0.38	9.43 ± 0.36 ns	9.76 ± 0.14	9.54 ± 0.15 ns
June 6	8.47 ± 0.51	9.86 ± 0.65 ns	12.80 ± 0.20	9.20 ± 0.20 *
July 12	8.82 ± 0.66	12.04 ± 0.64 *	11.44 ± 0.26	9.50 ± 0.19 *

*Indicates a significant difference (≥ 0.05) between seedling and scion on each date.

May, significant differences developed as the season progressed.

Although there were definite trends in leaf size, measurements of leaf function were more variable. When all of the data for the season were analyzed as paired comparisons for each measurement time, tall genotypes had significantly higher leaf conductances than the short genotypes both when grown as seedlings or as scions on the Marianna rootstock (Table 3). In general, the tall genotypes on the rootstock also maintained significantly higher leaf conductances than the same genotypes grown as seedlings. However, there were no significant differences in leaf conductance between short genotypes grown in the two ways (Table 3).

Field measurements of leaf photosynthesis were made less frequently and measured differences were less consistent. The tall genotypes grown as scions consistently maintained higher leaf photosynthetic rates than the short genotypes but there were no other consistent significant differences between any of the other plant combinations (Table 4).

Stem water potential data were quite variable and the only consistent differences were between the short genotypes growing as seedlings and scions on the Marianna rootstock (Table 5). The 10 small genotypes grown as scions had consistently higher stem water potentials than the same genotypes grown as seedlings.

Mean leaf concentrations of nitrogen and potassium in all 54 genotypes were significantly higher when grown as scions compared with seedlings (Table 6). Similarly, mean leaf chlorophyll concentrations per leaf unit area in all 54 genotypes were significantly higher when grown as scions (564 ± 12 mg m⁻²) compared with seedlings (431 ± 12mg m⁻²). There were no consistent significant differences in leaf phosphorus content.

Within the population of 54 seedlings there was a significant positive correlation between mean shoot length and leaf N concentration in June (Fig. 4). There was no significant correlation between the same factors in the same genotypes when grown as scions. There was a significant negative correlation between leaf K concentration and mean shoot length in June in the 54 seedlings, but again no significant correlation between the same two factors in the scions. (Fig. 5). Measurements made in May and July indicated similar patterns but the correlations were lower (data not shown).

Table 2. A comparison of mean (± se) leaf size (cm²) of the 10 tallest and 10 shortest seedling genotypes growing on their own roots and on Marianna 2624 rootstock at 3 sampling dates.

Date	Leaf Size (cm²)			
	Seedlings		Scions	
	Tall Genotypes	Short Genotypes	Tall Genotypes	Short Genotypes
May 10	10.37 ± 2.25	7.36 ± 1.81 *	9.70 ± 2.22	9.29 ± 2.66 ns
June 8	10.46 ± 2.38	6.15 ± 2.51 *	14.59 ± 4.92	7.60 ± 2.52 *
July 12	10.59 ± 4.25	4.51 ± 1.85 *	14.13 ± 3.45	9.66 ± 4.27 *

*Indicates a significant difference (0.05) between tall and short seedlings as determined by a Student's t-test.

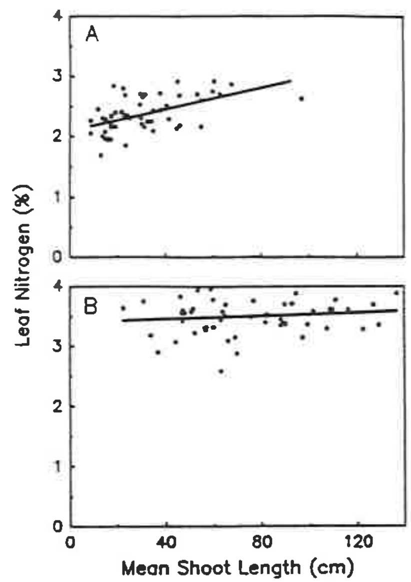

Figure 4. The relationship between mean shoot lenght and leaf nitrogen concentration in June 1988 of 54 *P. domestica* genotypes grown as seedlings (A, r = 0.53) and as scions (B, r = 0.12).

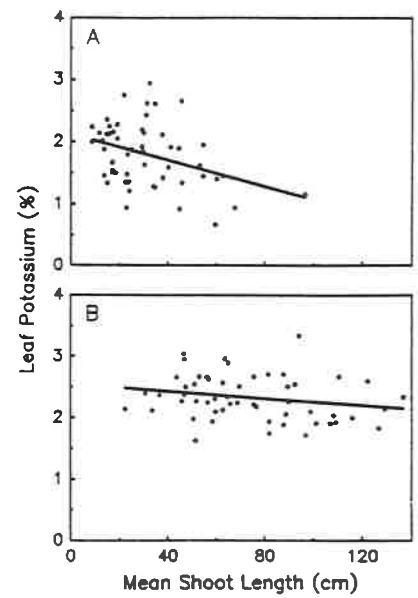

Figure 5. The relationship between mean shoot length and leaf potassium concentration in June 1988, of 54 *P. domestica* genotypes grown as seedlings (A, r = -0.36) and as seedlings (B, r = -0.21).

Discussion

Most seedling genotypes grafted onto the Marianna 2624 rootstocks clearly grew better than the same genotypes on their own roots during the 1988 growing season. There was some correlation between seedling growth and scion growth of the same genotypes and this relationship was established early in the growing season. Total mean shoot growth rates and percent of genotypes growing at any one time indicate that the young seedlings may be more susceptible to periodic growth flushes during the season than the grafted trees.

Seedling and grafted trees were growing in adjacent plots with the same soil type, irrigation and fertilizer treatments, but leaf N and K concentrations of the seedlings were consistently lower than the scions. The mean tissue N and K concentrations for both seedling and scions were in the range thought to be adequate for prune trees growing in California (1). There were significant positive correlations between seedling mean shoot length and leaf N concentration and negative correlations with leaf K concentration.

Table 3. Comparisons of leaf conductance to water vapor ($cm \cdot s^{-1}$) between the 10 tallest and 10 shortest seedling genotypes growing on their own root or on the Marianna 2624 rootstock.

		Leaf conductance ($cm \cdot s^{-1}$)			
		Seedlings		Scions	
Date†	Time	Tall genotypes	Short genotypes	Tall genotypes	Short genotypes
May 5	1000	0.85	0.60	0.78	0.71
	1500	0.68	0.57	0.81	0.65
May 11	1000	0.89	0.77	0.98	0.87
	1500	0.54	0.46	0.89	0.71
May 18*	1000	0.89	0.76	0.87	0.72
	1500	0.79	0.72	0.76	0.55
May 30	1000	1.12	0.88	1.11	0.90
	1500	0.82	0.67	0.84	0.65
June 20	1000	1.34	0.96	1.78	1.48
June 29	1000	1.01	0.74	1.27	0.90
July 14*	1000	0.89	0.82	0.96	0.88
	1500	0.81	0.89	1.03	0.86
July 20*	1000	1.19	1.12	1.50	1.30
		x----------0.01----------x		x----------0.01----------x	
		x------------------------0.05------------------------x			

†On most dates measurements were made twice, once during mid morning and a second time during mid afternoon (Pacific Standard Time). Each value is the mean of 30 measurements (3 measurements on 10 genotypes). Data were analyzed using a paired t-test to determine seasonal differences within and between seedling and grafted populations. The values at the bottom of the table indicate the level of significant differences between the various populations.
*Data from ADC apparatus, all other data from LI-COR instrument measurements.

The lower leaf N concentration in the slow growing seedlings could be partially related to the dilution effect of increased leaf mass per unit area (Table 1) that is associated with alterations in carbohydrate metabolism associated with N stress (5, 14). The correlation between shoot growth and leaf N concentration in the seedlings may represent an adaptive response to nitrogen supply similar to that reported for birch by Ingestad and Lund (7). Previous research with plum rootstocks has indicated significant genetic differences in root K uptake rate (R.M. Carlson, unpublished data) but little is known regarding genetic differences in N uptake capacity in *Prunus*.

Table 4. Comparisons of mean leaf photosynthetic rates ($\mu mol\ CO_2 \cdot m^{-2}s^{-1}$) between the 10 tallest and 10 shortest seedling genotypes growing on their own root or on Marianna 2624 rootstock. See Table 3 for details.

		Leaf Photosynthetic Rates ($\mu mol\ CO_2 \cdot m^{-2}s^{-1}$)			
		Seedlings		Scions	
Date	Time	Tall genotypes	Short genotypes	Tall genotypes	Short genotypes
May 5	1000	14.4	12.9	13.5	10.0
	1500	12.8	10.4	12.0	8.3
July 14	1000	11.0	11.4	12.1	11.4
	1500	10.7	10.9	11.4	9.8
July 20	1000	14.8	12.7	14.4	13.2
		x-----------ns-----------x		x----------0.05----------x	
		x------------------------ns------------------------x			
			x------------------------ns------------------------x		

Table 5. Comparisons of stem water potentials (mpa) between the 10 tallest and 10 shortest seedling genotypes growing on their own root or on Marianna 2624 rootstock. (See Table 3 for details.)

		Stem Water Potential (mpa)			
		Seedlings		Scions	
Date	Time	Tall genotypes	Short genotypes	Tall genotypes	Short genotypes
May 5	1000	-0.67	-0.89	-0.82	-0.61
May 11	1000	-0.73	-1.20	-0.74	-0.77
	1500	-1.32	-1.67	-1.27	-1.14
July 22	1500	-1.83	-1.63	-1.57	-1.50
		x-----------ns-----------x		x----------ns----------x	
		x------------------------ns------------------------x			
			x------------------------0.05------------------------x		

The tall genotypes maintained higher leaf conductance and photosynthetic rates than the short genotypes when both were grown as scions. This occurred even though there were no apparent differences in leaf water potential or leaf nutrient content between these particular genotypes grown as scions. Thus there appears to be a genetic difference in leaf photosynthetic potential between genotypes that was related to the differences in seedling growth. Although it has been demonstrated for other species (9) this type of relationship is relatively rare in studies of crop physiology (13). Plant growth and crop productivity are generally found to be more strongly related to light interception and resource partitioning than individual leaf photosynthesis under light saturated conditions (6). Perhaps one of the reasons why the relationship was apparent among the genotypes grown as scions was because differences in carbon partitioning to the root may have been minimized by using a common rootstock.

Because the correlation between seedling growth and scion growth of the same genotypes was limited it would appear unwise at this time to use seedling vigor (as reflected by height) in closely planted breeding populations as selection criteria in a breeding program of *P. domestica*. Seedling height appears to be substantially affected by environmental factors not directly related to their potential as scions and therefore its use for selection could eliminate genotypes with good scion growth potential and

Table 6. Mean (± se) leaf concentrations (% dry wt.) of nitrogen, phosphorus and potassium of the populations of 54 genotypes grown as seedlings and scions on Marianna 2624 rootstock on 3 different sampling dates in 1988.

	Nitrogen		Phosphorus		Potassium	
Sample Date	Seedlings	Scions	Seedlings	Scions	Seedlings	Scions
May 5	2.24 0.04*	3.30 0.06	0.24 0.01*	0.30 0.01	1.74 0.06*	2.45 0.04
June 8	2.37 0.04*	3.50 0.04	0.32 0.01ns	0.34 0.01	1.80 0.07*	2.33 0.05
July 13	2.43 0.05*	3.29 0.04	0.36 0.01ns	0.33 0.01	2.11 0.08*	2.48 0.06

*Indicates significant differences (0.05) between seedlings and scions as determined by Student's t-test.

fruiting characteristics that are not expressed due to poor root adaptability or other factors.

It would appear that grafting or budding *P. domestica* seedlings onto adapted rootstocks shortly after germination may be an efficient means of evaluating highly variable progeny. Although this method is labor intensive during the establishment phase, it should insure a more uniform evaluation of progeny potential. Furthermore, experience indicates that it is easier to maintain grafted trees than seedlings. At this point we do not know if genotypes treated as scions are more precocious than their seedling counterparts.

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McIntosh "Stamped"

The McIntosh apple was featured on the cover and described in *Fruit Varieties Journal*, Volume 44, Number 2, 1990. Subsequently, Canada issued, on December 27, 1991, three definitive stamps in a series entitled "Fruit Trees in Canada"; McIntosh apple is featured on the 48-cent stamp.

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Fruit Varieties Journal 47(1):47-51 1993

Scab Occurrence on Pecan Clones in Alabama in a Year of High Disease Incidence[1]

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Abstract

Occurrence of scab, a fungus disease of pecan (*Carya illinoensis* (Wangenh.) K. Koch) caused by *Cladosporium caryigenum* (Ell. et Lang.) Gottwald [= *Fusicladium effusum* Wint.) was rated on 63 pecan clones at five locations in Alabama during a year of high disease incidence. Locally-selected clones of seedling origin, 'Deakle's Special,' 'Dixie,' and 'Gafford,' were entirely free of scab symptoms on both nuts and leaves of unsprayed trees. Advanced USDA selections 70-3-34 and 72-2-9 had very low scab incidence. Seven other USDA selections, 75-5-32, 78-15-51, 72-6-36, 76-7-41, 73-1-10, 72-10-51, and 70-4-9 had significantly worse scab than did the standard cultivar 'Desirable.'

Introduction

Scab is the most destructive and widespread disease of pecan (4). Cultivars vary greatly in susceptibility, and genetic resistance is a primary goal in breeding and selection of potential new cultivars for humid locations (8). In Alabama in 1991, preliminary observations in midseason indicated unusually high scab incidence following rainy humid weather that predominated throughout the state during spring and summer. This unusual season provided an uncommon opportunity for evaluating scab incidence, which was high even on fungicide-treated trees. The need for this information on promising clones, including many being considered for expanded evaluation by the USDA pecan breeding program, prompted this report. No published information on scab incidence is available for many of the clones evaluated in this report.

Materials and Methods

Scab incidence was rated at five locations in the southern half of Alabama during 1991. Four locations were experimental orchards with trees planted in a randomized, replicated test, and the other location was a grower's unsprayed orchard. The modified Barratt-Horsfall rating system proposed and illustrated by Bertrand (1) was used for all ratings. The ratings are based on the percent surface area visibly affected by symptoms: 1 = no disease, 2 = trace-6%, 3 = 7-25%, 4 = 26-50%, 5 = 51-75%, 6 = 76-94%, 7 = 95-99%, and 8 = 100%. Data from each location were subjected to statistical analysis, using analysis of variance procedures with mean separations using Duncan's Multiple Range test. The methods allowed for comparisons among cultivars at a given location, but not for comparisons across locations.

Ainsley orchard. This orchard located near Foley in Southwest Alabama is comprised of 11 clones topworked onto nine-year-old 'Cape Fear' trees in 1987. The design is a randomized complete block, with three single tree replications. Most of the clones are seedling selections from Alabama. The clones were included in the experiment because of previous observations of

[1]Alabama Agricultural Experiment Station Journal Series 11-913193. We express our appreciation to Fountain Young, Walter Hogue, Don E. Campbell, Ronnie McDaniel, Emmett Carden, Leslie Brasher, M. B. Clemons, Bob Ainsley, Gus Tompkins, Wincen Williams, Mike Dennison, and Billy Deakle for their assistance with research.

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