

Inheritance of Procumbent Habit from 'Cipo' Sweet Orange in Crosses with 'Clementine' Mandarin

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ABSTRACT. 'Cipo' sweet orange [*Citrus sinensis* (L.) Osbeck] combines typical midseason fruit characteristics with a unique procumbent growth habit. This distinctive habit may be of value in breeding smaller and more procumbent scion cultivars if the growth habit is transmitted to hybrid seedlings. Two hybrid populations were created using 'Clementine' mandarin (*Citrus reticulata* Blanco) as the female parent and either 'Cipo' sweet orange or 'Pineapple' (another midseason sweet orange with a more typical upright growth habit) as the male parent. The 'Clementine' x 'Cipo' cross yielded many hybrids with the procumbent habit, many with the upright habit, and some that appeared intermediate. Both hybrid populations were compared with nucellar seedling populations from 'Cipo' and 'Pineapple' using two morphological characteristics that differentiate between the procumbent habit of 'Cipo' and the upright habit of 'Pineapple'. All the 'Clementine' x 'Pineapple' hybrids were of upright growth habit, while the 'Clementine' x 'Cipo' progeny segregated into two groups based on growth habit (upright and procumbent). The two measured characteristics were tightly correlated in the segregating population and are probably pleiotropic effects of the same genetic mutation. The observed population distributions were as expected if the procumbent habit in 'Cipo' is controlled by a single dominant allele in the heterozygous condition.

Breeding new citrus scion cultivars is a long and complex task because of the long life cycle of most *Citrus* species (Sherman and Lyrene, 1983), preponderant apomixis (Frost and Soost, 1968), and frequently complex inheritance patterns (Hutchison, 1985; Soost and Cameron, 1975). Despite these limitations to citrus breeding in general, significant success has been achieved in developing new cultivars through hybridization with a mandarin as the female parent, because there are many mandarins with predominantly zygotic embryony. Notable hybrids produced in breeding programs that have achieved some commercial importance include 'Fortune' (mandarin x mandarin), 'Kiyomi' tangor (mandarin x sweet orange), and 'Minneola' tangelo (grapefruit x mandarin) (Saunt, 1990; Tucker et al., 1993). Various more-complex hybrids with mandarin, such as 'Sunburst' (Hearn, 1979) and 'Ambersweet' (Hearn, 1989), have also gained considerable commercial importance in recent years.

Fruit quality and yield are usually of the greatest importance in developing new scion cultivars. However, other factors can be important in determining the long-term acceptance of a new cultivar. Uniformity of fruit, shipping and storage ability, ease of propagation, and strength of tree structure must also meet certain standards for a cultivar to succeed among producers and in the market. Tree size and growth habit may also be important. Management of citrus plantings has traditionally relied on pesticides, inexpensive labor, and high crop returns. Changes that are occurring in pesticide regulations, labor, and the marketplace may force growers to consider production systems that are more efficient and easier to manage and harvest. One approach to improving production system efficiency may be using smaller trees that do not

require hedging or ladders for harvest. Some tree size regulation can be obtained by rootstock influence (Castle et al., 1993; Roose, 1990). However, acceptable tree size control by rootstock, along with other desirable rootstock characteristics, is often not possible with existing rootstock cultivars.

An alternative way to regulate tree height is by the genetic growth habit of the scion. 'Cipo' sweet orange is a typical midseason sweet orange, except that it exhibits an unusual procumbent growth habit that can be observed in mature trees and nucellar (apomictic) seedlings (Bowman, 1994). A similar procumbent habit may be an asset to some new citrus cultivars possessing other desirable production and market characteristics. Therefore, the procumbent habit of 'Cipo' could be a useful trait in citrus cultivar development.

The objectives of this study were to 1) determine whether the procumbent habit of 'Cipo' is recovered among hybrid progeny with 'Clementine' mandarin (a monoembryonic zygotic breeding parent) and compare this progeny with a similar hybrid progeny from a sweet orange exhibiting a normal growth habit; 2) quantify the frequency and degree of procumbent and/or normal growth habits observed; and 3) develop a preliminary hypothesis for the genetic control of the procumbent trait.

Materials and Methods

Controlled crosses were made with 'Clementine' mandarin (CRC 279) in the Citrus Variety Collection at the Univ. of California, Riverside, during Spring 1992 using pollen from 'Cipo' (CRC 3896) and 'Pineapple' (CRC 3858) sweet oranges. Hybrid seed from these crosses and open-pollinated nucellar seed from the same 'Cipo' and 'Pineapple' clones were collected in Fall 1992 and planted in soilless potting mix at the Whitmore Foundation Farm, near Orlando, Fla. Seedlings of all four populations were transplanted to 4-L pots during Spring 1993 and grown under natural lighting in warm greenhouse conditions for the following 2 years. Plants were watered as needed and fertilized twice per month with a standard water-soluble fertilizer.

Shoot altitude, extension, and leaf petiole angle were measured on seedlings as described previously (Bowman, 1994), except that

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Table 1. Description of the four citrus populations with numbers of seeds and plants represented in each aspect of the study.

Seedling genotype	Seeds planted	Seeds germinated	Healthy plants evaluated ²	
			Shoot	Petiole
Pineapple nucellar	96	79	81	74
Cipo nucellar	83	70	84	79
Clementine x Pineapple	189	177	129	74
Clementine x Cipo	329	294	170	88

²Polyembryonic cultivars like 'Pineapple' and 'Cipo' sometimes produce multiple seedlings from single seeds so that more seedlings can be obtained than there are seeds that germinate. 'Clementine' is a monoembryonic cultivar that produces only one seedling per seed.

the techniques were modified to allow replicated measurements on individual plants and to accommodate the greater diversity of growth rates among the hybrids. After a period of initial growth, seedlings were pruned by removing side shoots and cutting the main shoot at a height ranging from 15 to 30 cm. Two shoots were then allowed to regrow from axillary buds on the single main trunk. When both shoots on a seedling achieved a length (extension) of at least 10 cm, altitude of the shoot tip and extension of the shoot tip were measured from the base of each regrowth shoot. Altitude was measured as the elevation of the shoot tip above the base of the shoot as it hung naturally, while extension was the total length of the shoot from base to tip when it was fully straightened. One method of quantifying shoot straightness and uprightness (as it relates to the procumbent growth habit of 'Cipo') is to calculate the ratio of shoot altitude to shoot extension. Shoots that grow upright will have a ratio of ≈ 1 , while shoots that grow or bend toward the horizontal will have smaller ratios. Separate altitude/extension ratios were calculated for each regrowth shoot. After the first cycle of leaf petiole angle measurements described below, this process of pruning, regrowth, and measurement of shoot altitude and extension was repeated a second time on as many selections as possible. Mean altitude/extension for each seedling was calculated as an average of the 2 to 4 shoot ratios (2 shoots per seedling \times 2 cycles).

After the first set of altitude/extension measurements was made on each seedling, one shoot was removed and the remaining shoot was trained to an upright stake. Shoots on individual plants were carefully monitored and staked upright until they achieved a length of at least 45 cm. Petiole angle was then measured on five normal mature leaves within the middle 33% of this length (15 cm $< x <$ 30 cm). Leaves located adjacent to where a terminal bud had been formed (at the beginning or end of a growth flush) were not chosen for measurement because it had been noted previously that these leaves were often atypical. The process of pruning to a single shoot, training to an upright stake, and measurement was completed a second time after the second cycle of shoot altitude/extension measurement. Mean petiole angle for each seedling was calculated as the average of 10 leaf petiole angles. Data analysis and figures were prepared using Statistica/W version 4.5 (StatSoft, Inc., Tulsa, Okla.).

Results

Flowering time for 'Clementine' and the two sweet oranges overlapped significantly during 1992 in Riverside, continuing from the first week of March through the first week of April. About 62% and 88% of 'Clementine' flowers pollinated with 'Pineapple' and 'Cipo', respectively, set fruit that remained on the tree until they were harvested for seed. An average of 19 and 22 seeds per fruit for 'Clementine' crossed with 'Pineapple' and 'Cipo', respectively, indicated that the parental combinations were compatible.

Most of the seeds from all four populations germinated and grew during the first months after planting. Some of the seedlings, especially from the 'Clementine' \times 'Cipo' cross, died during the tests or failed to grow sufficiently for the quantitative measurement of shoot altitude/extension. Adequate shoot data could be obtained on only $\approx 58\%$ (170/294) of the 'Clementine' \times 'Cipo' seedlings that began to grow (Table 1), while similar information could be collected from 90% (84/93) of the nucellar 'Cipo' seedlings that were produced. 'Pineapple' and 'Cipo' are polyembryonic (sometimes producing multiple seedlings from a single seed), so the open-pollinated seeds from those cultivars yielded more seedlings than the number of seeds planted. Fewer seedlings of all populations grew adequately for completion of petiole angle measurements because this required considerable additional growth. However, the losses from the 'Clementine' \times 'Cipo' population were again much larger than for the other populations.

The ratio of shoot altitude/extension was clearly different between 'Pineapple' nucellar seedlings (0.82) and 'Cipo' nucellar seedlings (0.20), separated by the LSD test at $P < 0.01$ (Table 2). This difference was apparent by casual examination (Fig. 1 A and B). However, measurable variation was evident within each of these two seedling populations when this characteristic was quantified (Fig. 2 A and B). The shoot ratio for each population appeared to be normally distributed with a single peak evident in the distribution. No overlap for this trait was observed between these two populations: 'Pineapple' ratio > 0.6 , while 'Cipo' ratio < 0.6 .

Every individual in the 'Clementine' \times 'Pineapple' hybrid population should be genetically different from other offspring from the same cross and both parents for many characteristics. This

Table 2. Means, standard deviations, and comparisons of four citrus populations for shoot altitude/extension ratio and petiole angle.

Seedling genotype	Shoot altitude/extension ratio		Petiole angle (degrees)	
	Mean	SD	Mean	SD
Pineapple nucellar	0.82 A ²	0.08	69 A	7
Cipo nucellar	0.20 C	0.11	99 C	8
Clementine x Pineapple	0.76 A	0.11	67 A	11
Clementine x Cipo	0.60 B	0.25	80 B	19

²Mean separation, within columns, by LSD test, $P < 0.01$.

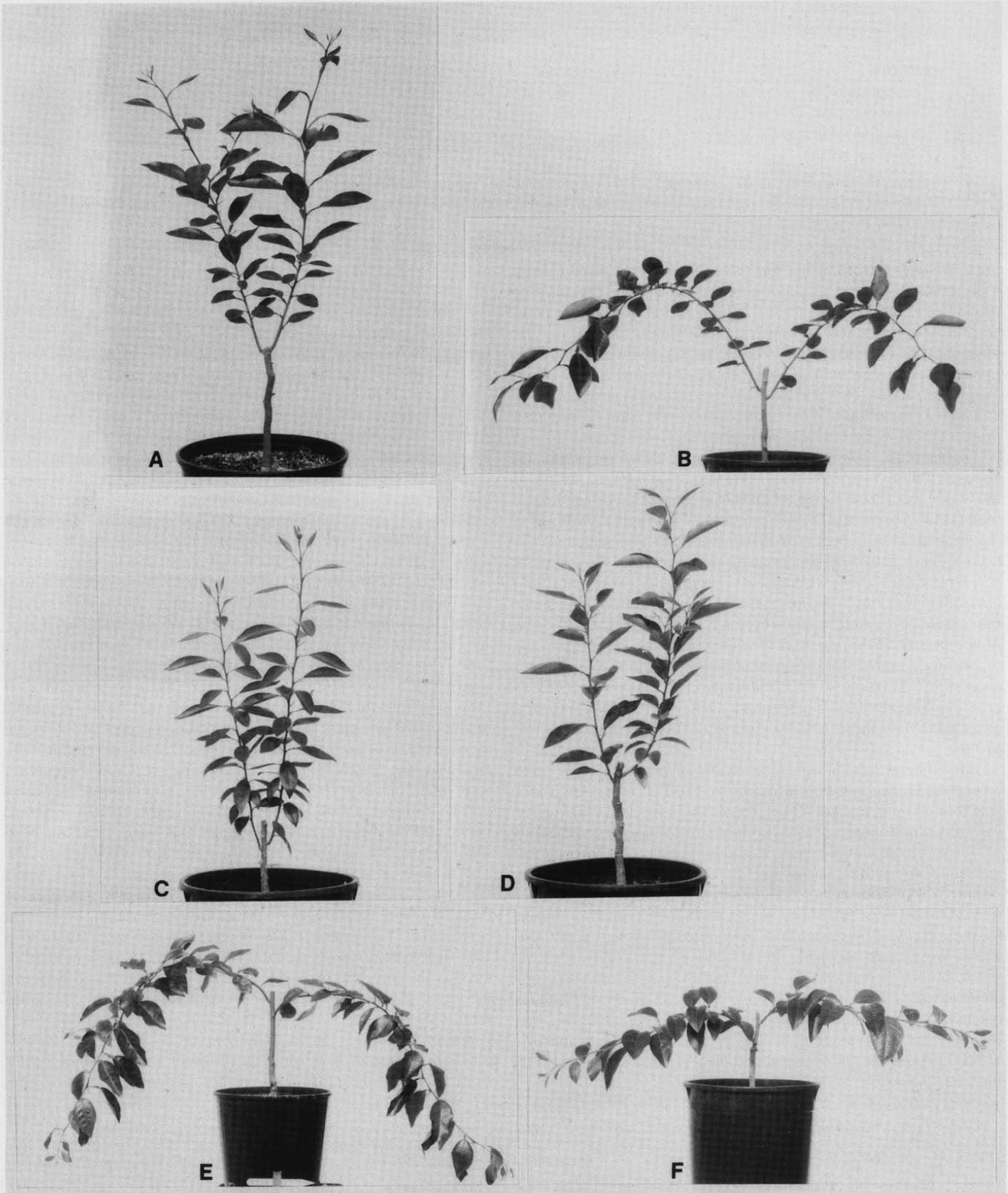


Fig. 1. Comparison of typical shoot growth habits for (A) 'Pineapple' nucellar seedlings; (B) 'Cipo' nucellar seedlings; (C) 'Clementine' x 'Pineapple' hybrid seedlings; (D) upright 'Clementine' x 'Cipo' hybrid seedlings; and (E-F) procumbent 'Clementine' x 'Cipo' hybrid seedlings.

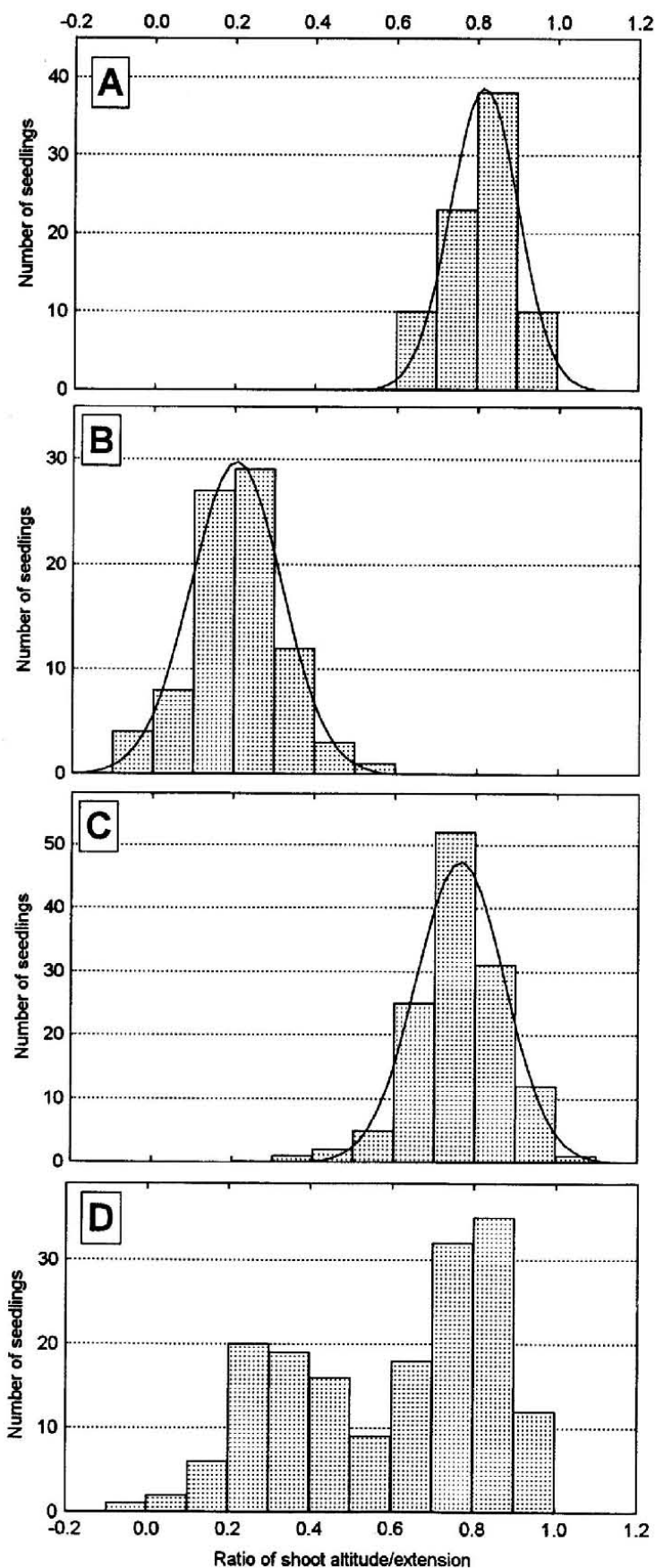


Fig. 2. Distribution of mean altitude/extension ratios with the proposed corresponding normal distribution curves for populations of (A) 'Pineapple' nucellar seedlings; (B) 'Cipo' nucellar seedlings; (C) 'Clementine' x 'Pineapple' hybrid seedlings; and (D) 'Clementine' x 'Cipo' hybrid seedlings.

was most easily detectable with the young seedlings on the basis of leaf shape, but would undoubtedly apply to many other traits as well (such as fruit size, shape, and color). Despite the genetic diversity, the shoot altitude/extension for this hybrid population had a mean and distribution that was very similar to 'Pineapple' nucellar seedlings (Fig. 1C, 2C). The LSD test did not distinguish the 'Clementine' x 'Pineapple' hybrid population from the 'Pineapple' nucellar population but did distinguish it from the 'Cipo' nucellar population ($P < 0.01$). Standard deviation of shoot ratio in the 'Clementine' x 'Pineapple' population was similar to that for each of the two nucellar populations that lacked any genetic variation (Table 2). Based on this observation, there appeared to be very little genetic variation for shoot ratio within the 'Clementine' x 'Pineapple' hybrid population.

Substantial diversity for shoot ratio was observed within the 'Clementine' x 'Cipo' hybrid population. In contrast to the 'Clementine' x 'Pineapple' hybrid population, the standard deviation for shoot ratio in the 'Clementine' x 'Cipo' hybrid population was more than twice that of either nucellar population. The measured values for shoot ratio spanned the range of the 'Pineapple' nucellar and 'Cipo' nucellar populations combined and the LSD mean separation ($P < 0.01$) distinguished this hybrid population from either nucellar population. The population distribution appeared bimodal, with means of the two groups approximating the locations of the means for 'Pineapple' and 'Cipo' nucellar seedlings (Figs. 1D-F and 2D).

The mean petiole angle of 69° for 'Pineapple' nucellar seedlings was distinguished from the 'Cipo' nucellar seedling petiole angle of 99° by the LSD test at $P < 0.01$ (Table 2). As was the case for shoot ratio, considerable variation in petiole angle was evident within each nucellar population and each of the two nucellar populations appeared normally distributed for this trait (Fig. 3A and B). However, there was some overlap for mean petiole angle between the two populations of nucellar seedlings, and this trait alone could not be used to discriminate clearly all 'Pineapple' nucellar from all 'Cipo' nucellar seedlings.

The 'Clementine' x 'Pineapple' hybrid population was slightly more variable for petiole angle than either nucellar population (Fig. 3C). However, mean petiole angle for this group of hybrids was nearly identical to the 'Pineapple' nucellar population (Table 2) and appeared to be composed of a single normal distribution. The LSD test ($P < 0.01$) separated the 'Clementine' x 'Pineapple' population from the 'Cipo' nucellar population but did not separate it from the 'Pineapple' nucellar population (Table 2). There appeared to be relatively little genetic variation for petiole angle within the 'Clementine' x 'Pineapple' population.

In contrast, the 'Clementine' x 'Cipo' hybrid population had a standard deviation for mean petiole angle more than double that of either nucellar population (Table 2) and a range that equaled that of both nucellar populations combined (Fig. 3D). The distribution of individuals within this hybrid population for petiole angle did not appear to form one group, but could not be divided unambiguously into two groups. However, the 'Clementine' x 'Cipo' population distribution appeared consistent with segregation into two groups, with group means approximately the same as the means for the 'Pineapple' and 'Cipo' nucellar seedlings.

The 'Pineapple' and 'Cipo' nucellar populations were clearly distinguished from each other when each seedling's petiole angle and shoot altitude/extension ratio were plotted and compared graphically (Fig. 4A). 'Pineapple' nucellar seedlings have rela-

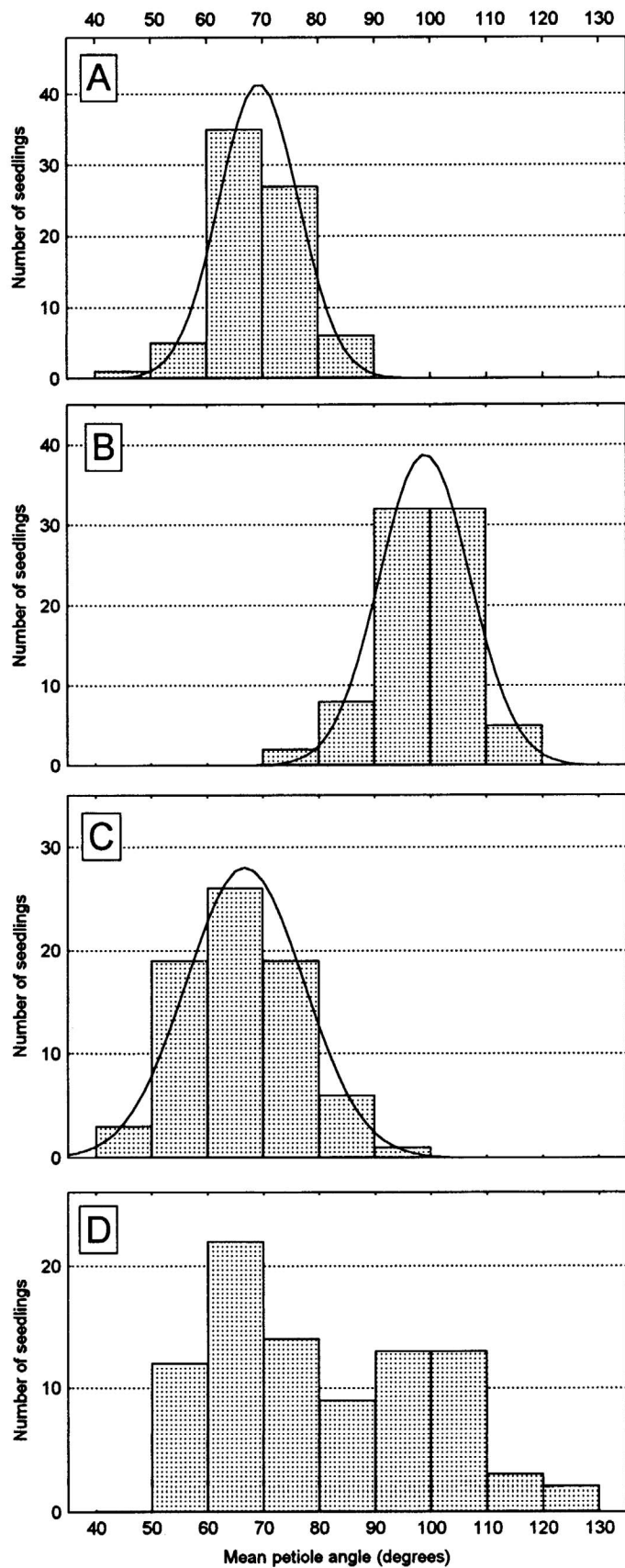


Fig. 3. Distribution of mean petiole angle (in degrees) with the proposed corresponding normal distribution curves for populations of (A) 'Pineapple' nucellar seedlings; (B) 'Cipo' nucellar seedlings; (C) 'Clementine' x 'Pineapple' hybrid seedlings; and (D) 'Clementine' x 'Cipo' hybrid seedlings.

tively large shoot altitude/extension ratios combined with relatively small petiole angles, while 'Cipo' nucellar seedlings have small shoot altitude/extension ratios combined with large petiole angles. Within each cultivar, no clear relationship appears to exist between the two measured traits: seedlings with large petiole angles were no more likely to have small shoot altitude/extension ratios than other nucellar seedlings of the same cultivar. The approximate regions occupied by seedlings of these two genotypes are demarcated by dotted brackets in Fig. 4A.

A similar plot of individual seedling means for the 'Clementine' x 'Cipo' population should give an indication of the degree of recombination between the two characteristics. Seedlings plotted in two regions would indicate potential recombinants (Fig. 4B). One region (R1) would combine a small petiole angle with a small shoot altitude/extension ratio. Only one of the 87 'Clementine' x 'Cipo' hybrid seedlings scored for both traits was located in this region, and it was relatively close to the region identified for 'Pineapple' nucellar seedlings. The second region of potential recombinants (R2), where large altitude/extension ratio is combined with a large petiole angle, contained four hybrid seedlings. However, all of these were very close to the regions identified for 'Pineapple' or 'Cipo' nucellar seedlings.

Discussion

'Clementine' is completely monoembryonic and self-incompatible (Hodgson, 1967); therefore, none of the seedlings obtained from the controlled crosses were either nucellar clones or the result of self-fertilization. The expectation that all 'Clementine' seedlings would be hybrids was supported by the diversity of morphologies and growth characteristics apparent in the hybrid populations (although there was not a similar diversity in shoot ratio or petiole angle). 'Clementine' was used as the female parent in this study because it would produce all hybrid seedlings and because some 'Clementine' x 'Cipo' hybrids might reasonably be expected to have sufficient fruit quality for a commercial tangerine. In contrast, the open-pollinated seedlings of 'Cipo' used in this study were probably all of nucellar origin and genetically identical to the parental tree. Evidence for this includes the morphological uniformity within this seedling population and a previous isozyme analysis that indicated that <1% of open pollinated 'Cipo' seedlings are of zygotic origin (Bowman et al., 1995). For similar reasons, the open-pollinated 'Pineapple' seedlings used in this study were probably all genetically identical to the parent tree. No off-type plants were observed among these seedlings for either sweet orange cultivar.

A previous report (Bowman, 1994) that the difference in growth habit of mature 'Pineapple' and 'Cipo' trees is readily detected in young clonal seedlings by measuring shoot altitude, extension, and petiole angle is clearly supported by the results shown here. Although no data were taken, casual observation indicates that 'Clementine' has similar shoot growth and petiole angle to 'Pineapple'. In fact, most citrus types resemble 'Pineapple' in growth habit (and are dissimilar from 'Cipo'). A procumbent shoot habit is rarely observed in the genus *Citrus*, except in some autotetraploids and somatic hybrids (F.G. Gmitter and J.W. Grosser, personal communication), and rarely in seedling populations. The similar means and standard deviations for 'Pineapple' nucellar seedlings (all genetically identical) and the 'Clementine' x 'Pineapple' hybrid population indicates that there is relatively little genetic variation for shoot altitude/extension ratio and petiole angle within that hybrid population. Casual observation suggests that there may be relatively little genetic diversity for these traits

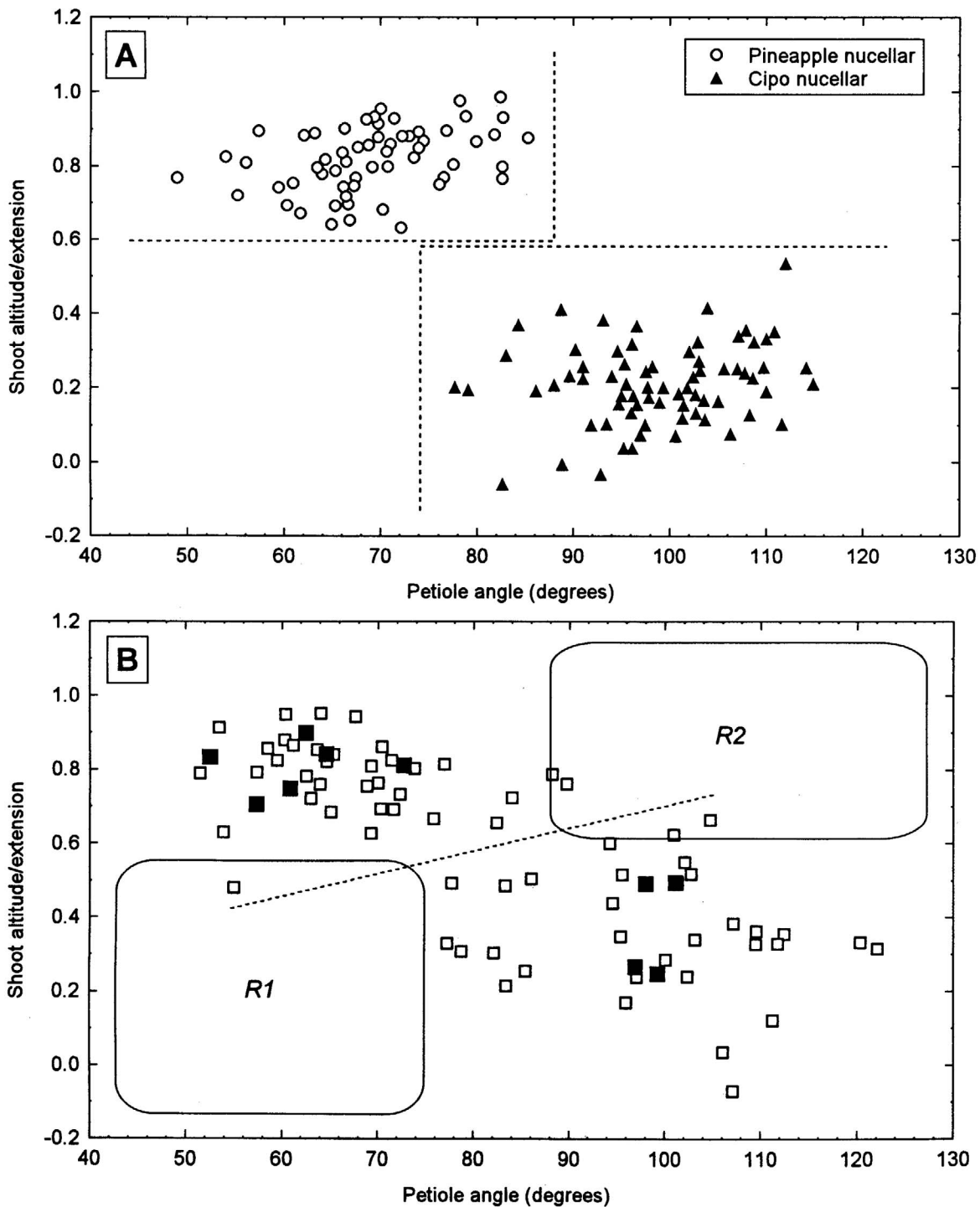


Fig. 4. Comparison of petiole angle with shoot altitude/extension from seedlings for which both types of data were complete. (A) 'Pineapple' (○) and 'Cipo' (▲) nucellar seedlings (dotted lines demarcate the regions that are proposed as normal for 'Pineapple' and 'Cipo'); (B) 87 'Clementine' x 'Cipo' hybrid seedlings (□ for 1 seedling or ■ for 2 seedlings at same point) with the circled regions R1 and R2 indicating potential recombination areas. Dotted line indicates proposed demarcation between normal and procumbent groups within the population.

within most common citrus germplasm. The reduced survival of the 'Clementine' x 'Cipo' population when compared to the 'Clementine' x 'Pineapple' population provides one possible reason why the procumbent growth habit may be rare within *Citrus*: it may contribute negatively to the fitness of hybrids.

Only 5 of the 87 'Clementine' x 'Cipo' hybrid seedlings evaluated for both morphological characteristics showed possible

recombination between the two traits. These five possible recombinants were only slightly beyond the regions identified for the two nucellar populations and therefore may be the result of a slightly greater deviation within genetically diverse hybrid populations compared with genetically identical clonal populations, rather than the product of recombination. None of the seedlings from the 'Clementine' x 'Cipo' population showed a combination of ex-

Table 3. Chi-square tests for goodness-of-fit for the 'Clementine' x 'Cipo' population to 1:1 segregation ratio (df = 1 for all tests).

Trait	Normal		Procumbent		χ^2	P
	Observed	Expected	Observed	Expected		
Altitude/extension ratio ²	97	85	73	85	3.39	0.07
Petiole angle ³	51	44	37	44	2.23	0.136
Both ^x	48	43.5	39	43.5	0.93	0.335

²Division between normal and procumbent was made at 0.6 (based on parental data summarized in Fig. 2 A and B).

³Division between normal and procumbent was made in 80- to 90-degree category with 62% of hybrids in this category scored as procumbent and 38% scored as normal (based on parental data summarized in Fig. 3 A and B).

^xDivision between normal and procumbent was made along dotted line shown in Fig. 4B (based parental data summarized in Fig. 4A).

treme shoot altitude/extension ratio and extreme petiole angle that was clearly a recombination of the two traits from the parental types. This observation suggests that the two traits associated with the procumbent habit of 'Cipo' (small shoot altitude/extension ratio and large petiole angle) are caused by closely linked genes, or more likely by pleiotropy. The otherwise typical sweet orange morphology of 'Cipo' (Bowman, 1994) and the identical isozyme patterns shared between 'Cipo' and other sweet oranges (Bowman et al., 1995) suggest that 'Cipo' was produced by a relatively minor genetic mutation from another sweet orange selection rather than from sexual recombination or some gross genetic change. These facts, along with the logical similarity between the two measured effects (both resulting in more horizontal growth of aerial structures) suggest that the two traits are probably manifestations of one simple mutation. The mechanism of the mutation is as yet unknown, but altered hormone balance or sensitivity could be involved (Bowman, 1994).

Several factors suggest that the procumbent habit in 'Cipo' may be controlled by a single dominant mutation and that 'Cipo' is heterozygous at the locus involved. First, the likely origin of 'Cipo' by mutation of another sweet orange would suggest a single gene. Evidence has recently been presented (Cheng and Roose, 1995) to suggest a single dominant allele affecting stem and thorn morphology and rootstock-mediated scion size control in the citrus rootstock 'Flying Dragon' [*Poncirus trifoliata* (L.) Raf.]. In this study, the lack of much measurable genetic variation for either shoot ratio or petiole angle within the 'Clementine' x 'Pineapple' population and the paucity of similar or intermediate forms within *Citrus* suggest major gene rather than quantitative inheritance. Quantitative or multigenic inheritance of the procumbent habit also seems unlikely because of the large number of fully procumbent individuals identified within the 'Clementine' x 'Cipo' hybrid population. Fully procumbent types also have been obtained from 'Cipo' hybridization with other nonprocumbent parents (*Citrus grandis* [L.] Osbeck, *Citrus ichangensis* Swing., and *Poncirus trifoliata*) whether 'Cipo' was used as the seed or pollen parent (data not presented).

Second, 'Clementine', 'Pineapple', and most other citrus types do not appear to have recessive alleles for procumbent habit because hybrids that might be considered procumbent were not found within the 'Clementine' x 'Pineapple' population and are generally rare within other hybrid populations. Third, the population of hybrids between 'Clementine' and 'Cipo' appeared to have a bimodal distribution for both (probably pleiotropic) characteristics that were measured in this study. Further, each of these two groups within the hybrid population had means and ranges that were similar to those of the genetically uniform normal and genetically uniform procumbent populations, respectively. It is proposed that the possible mutant allele in 'Cipo' should be identified *CP* for 'Cipo' procumbent and the 'Cipo' genotype

identified as *CP/cp* at this locus. Using this system, the genotype of 'Pineapple', 'Clementine', and most other citrus would be identified as *cp/cp* at this locus.

Chi-square tests were performed to evaluate whether the F_1 population of 'Clementine' x 'Cipo' hybrids segregated into 1 procumbent : 1 normal, the expected ratio if procumbency is controlled by a single dominant allele in 'Cipo' (Table 3). The observed segregation of the hybrids was consistent with a 1:1 ratio ($P > 0.05$) whether they were evaluated by shoot altitude/extension ratio, petiole angle, or the two combined. Both characters associated with the procumbent habit (shoot ratio and petiole angle) segregated in patterns that were consistent with single gene control. However, it was clear that the fit to a 1:1 was not very good for any of the methods of evaluation because of a shortage of procumbent types. Examination of the population distributions provides one possible explanation for this skewing, when considered along with the observation of reduced fitness among the hybrids with 'Cipo': more of the procumbent hybrids (*CP/cp*) may have died or shown poor growth than the hybrids in the normal category (*cp/cp*). When evaluated for shoot altitude/extension ratio, the distribution of the 'Clementine' x 'Cipo' population (Fig. 2D) clearly appears to form two groups with means approximating those of normal ('Pineapple') and procumbent ('Cipo') genotypes (Fig. 2 A and B). However, the distribution of the procumbent group within this hybrid population appears to be truncated at its lower end, an observation that is especially apparent when this distribution is compared to that for 'Cipo'. Of the 294 'Clementine' x 'Cipo' seedlings that originally began to grow, half may have been normal genotype (*cp/cp*) while half were procumbent genotype (*CP/cp*). However, because of an effect of the *CP* allele to reduce fitness, more of the *cp/cp* individuals than *CP/cp* individuals may have survived or grown sufficiently for evaluation.

Confirmation of the genetic control of the procumbent habit in 'Cipo' by a single dominant allele will require a number of years for production and analysis of advanced generations. Until then, it seems apparent that many procumbent hybrids could be produced by F_1 hybridization with 'Cipo' as either pollen or seed parent. The large frequency of procumbent types within the F_1 suggests that advanced generations will also yield a significant number of fully procumbent types. The effect (and fitness) of a *CP/CP* genotype has not been assessed because of the difficulty of obtaining selfed individuals from 'Cipo'. Potentially, some of the 'Clementine' x 'Cipo' hybrids may be amenable to self-fertilization, backcross, or sib-crosses. Despite the reduced fitness that may be associated with the procumbent habit in some hybrids, the relative health and vigor observed in 'Cipo' nucellar seedlings suggest that at least occasional genetic combinations with procumbent habit may have good fitness. The commercial potential for procumbent citrus hybrids can only be determined by long-term field evaluation with hybrids like those produced in this study.

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