tance of breeding and selecting new cultivars in the region where they are intended to be grown.

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Early Flowering and Fruiting in Potted Citrus Trees: Exploitation for Mutation Breeding

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Many commercially-important tree fruit cultivars have originated as naturally occurring mutants. Irradiation of mature clones has been employed to increase the frequency of mutation in clonally propagated plants (9). Mutagenesis is appropriate when minor changes are desired in an otherwise acceptable cultivar, and it has been employed extensively to reduce seediness in *Citrus* (3, 7, 8). Mutation breeding may accelerate cultivar development in comparison with conventional breeding (i.e., genetic recombination) because the juvenile phase is circumvented in the former. Propagules derived from budwood of mature (vs. juvenile) clones may flower and fruit earlier in response to various inductive treatments including root confinement (10).

Two parameters represent major obstacles to the efficiency of cultivar development in woody plant species: (a) the lengthy juvenile period which precedes flowering and fruiting and thus delays cultivar evaluation and (b) large plant size which impedes cultivar improvement by limiting the number of propagules which can be maintained and evaluated (2).

Restricted root volumes have been used to stimulate early cropping at the expense of vegetative growth in peaches (1), apple (4, 6), and citrus (5), but the phenomenon has not been exploited widely for cultivar improvement. Root confinement in conjunction with mutation breeding may facilitate early screening of mutants as the ability of ontogenetically mature clones to flower is not dependent on the attainment of large plant size (10).

This study was undetaken to confirm the potential advantages of root confinement (as compared to the unconfined root system of field-grown

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[3]The authors wish to thank Professor P. Spiegel-Roy for valuable discussions, Dr. Shabtai Cohen for light measurements, and Mr. D. Saada for technical assistance.

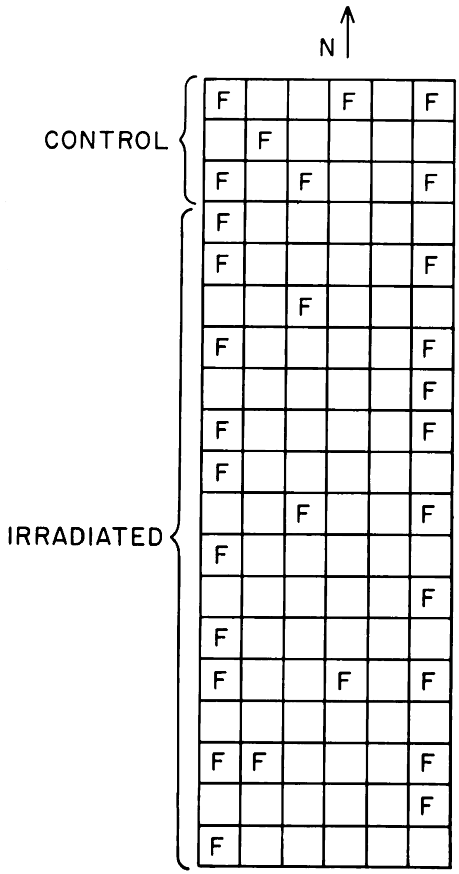

Fig. 1. Distribution of flowering (F) 'Niva' plants on a 3.0 x 1.1 m bench 10 months after grafting of irradiated and non-irradiated buds on Troyer citrange rootstocks. Eighteen plants in the three rows at the north end of the bench were derived from one-bud portions of untreated shoots, and the remaining 96 plants were derived from irradiated (4000 r) shoots. Empty slots represent non-flowering plants.

plants) on the length of the vegetative period and the size of irradiated plants at fruiting. Parameters such as seedlessness should be determinable on small plants as few fruit are required for the preliminary screening to identify the low percentage of seedless mutants which may occur.

Materials and Methods

We chose the tangor Niva [Wilking (*C. reticulata* Blanco) x Valencia (*C. sinensis* [L.] Osbeck] as our test cultivar because of its reported precocity (P. Spiegel-Roy, personal communication). Shoots (budwood) were cut from an adult, bearing Niva tree and either left untreated (control) or exposed to ^{60}Co rays until a 4000-r dose had been administered (9). Irradiated and control shoots were then subdivided into one-bud portions and budded (in May) 20 cm above the soil surface on one-year-old Troyer Citrange [*Poncirus trifoliata* (L.) Raf. x *C. sinensis*, cultivar Washington Navel] rootstocks growing in 4-liter pots. Bud-take of Niva was virtually 100% following exposure to 4000 r. Plants were maintained in a screenhouse but, otherwise, no supplementary heating or cooling was used. Plants were irrigated and fertilized as needed.

Results and Discussion

Delayed sprouting of irradiated buds (vs. control) and malformations of the first few true leaves were observed as previously described for Shamouti orange (9). Thirty Niva trees flowered in March, i.e., 10 months after irradiation and grafting (Figs. 1, 2). Thus, the characteristic vegetative period of these plants was reduced by one-half under our experimental conditions. Niva trees have not flowered in the field sooner than two years after budding (P. Spiegel-Roy, personal communication). The advantage of root confinement may be even greater if less precocious cultivars were to be tested.

A higher percentage of control plants (39%) than of irradiated plants (24%) flowered, but this apparent repression of flowering by irradiation may reflect the delayed sprouting of irradiated buds following grafting as previously mentioned.

Fig. 2. Fruiting 'Niva' tree developed from irradiated bud. Tree was grafted May 1981, and the photograph taken November 1982.

At the time of flowering, the plants averaged 70 cm in height, i.e., 50 cm above the bud union. Typically, two secondary branches were produced from the main axis before the reproductive flush had occurred. Fruit retention was promoted by elimination of competing vegetative sinks, and flowering plants carried 3 or 4 fruit to maturity (Fig. 2).

Edaphic factors such as soil water tension or evapotranspiration rate rather than root confinement *per se* may be the primary means by which root confinement accelerates flowering. Thus, although only 25% of our plants flowered overall, 61% of the plants in the east and west border rows flowered and fruited, whereas only 11% of the plants flowered in the four interior rows (Fig. 1). The possibility that the effects of small pots on flowering are in general mediated by transient water stresses remains unresolved in the literature.

Mid-day summer readings of PAR were taken using a Lambda LI-185A meter equipped with a LI-190S quantum sensor. Values above the bench within the screenhouse were 700 $\mu Em^{-2}sec^{-1}$, a 67% reduction from the 2100 $\mu Em^{-2}sec^{-1}$ reading taken at the same time outside the screenhouse. Light measurements taken under the leaf canopy (at the height of the bud union) 6 cm from the plant stems varied between 40 and 80 $\mu Em^{-2}sec^{-1}$ along the border rows (where flowering was more prevalent), and between 5 and 20 $\mu Em^{-2}sec^{-1}$ along the interior rows.

Thus, under the ambient light conditions, we believe that shading associated with high plant density (35 plants/m^2) may have depressed the level of flowering which would have otherwise occurred.

Root confinement may hasten initial screening and selection of potentially-useful mutants (e.g., seedless) following irradiation. Irradiated plants (like unirradiated controls) flowered and fruited in half the time required in the field on a tree structure occupying one-fourth the area occupied by trees growing in the field as they come into fruiting (E. Salomon, unpublished data).

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