Studies on the Establishment of Date Palm (*Phoenix dactylifera* 'Deglet Noor') Offshoots. Part I. Observations on Root Development and Leaf Growth

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Date palm cultivars are clones that must be propagated vegetatively, the grower nearly always relying on offshoots (young plants) that arise from the base of the mother palm. We found that offshoots possessing more roots when removed from the mother palm have a greater ability to regenerate a root system and to establish more successfully and rapidly because over two-thirds of all new roots grew from existing cut roots. Leaf extension is a good above-ground indicator of root growth.

This article is the first of two exploring establishment of date palm offshoots. Part II will appear in a future issue of *Palms* and will address the optimal size for best establishment.

The date palm, *Phoenix dactylifera* L., has long been one of the most important plants of arid, desert areas of northern Africa, the Middle East and southern Asia. Appropriately called "the palm of life," for over 5,000 years it has provided food, ornament and material for shelter, fiber, and fuel in a harsh environment where relatively few other plants are able to grow (Dowson 1982, Nixon & Carpenter 1978, Popenoe 1973, Zaid 1999). Humans have since spread the date palm far beyond its historical range, taking it to nearly all regions of the world where it can be grown. Even in more humid tropical and subtropical areas unsuitable for fruit production, the date palm is widely used as an ornamental palm.

In USA commercial date fruit production began in the late 1800s and is still an important component of desert agriculture in southern California and Arizona (Albert & Hilgeman 1935, Johnson et al. 2002, Karp 2002, Nixon & Carpenter 1978). Since the late 1970s and continuing to the present, steady economic growth and subsequent real estate boom in the south-western and southern United States have fuelled an unusually strong and steady demand for large landscape palms.

Mature date palms are highly desirable landscape subjects because they are plentiful, relatively inexpensive, uniform in size and habit, and highly ornamental. Dug out of date groves in California and Arizona, the palms are transported for outdoor landscape planting within these states as well as to southern Nevada, Texas, and Florida, and sometimes even for indoor use elsewhere.

Most date growers have found it more profitable to sell date palms for landscape use, once they attained a desired height of 8–10 meters of trunk, than to continue to grow them solely for fruit production (D. Young & W. Geissler pers. comm., Karp 2002). Planted about 50 palms per acre (0.4 ha.), the palms begin to produce harvestable fruits after three to five years, steadily increasing to full production at 15–20 years. Growers can annually net US $500–1,000 per acre at full production. However, they can net about US$50,000 per acre when the palms have reached the desired height and are harvested and sold for landscape use, usually in 20–25 years (D. Young & W. Geissler pers. comm., Karp 2002). Indeed, much of the recent expansion of date palm acreage in California and Arizona is due as much, if not more, to the demand for the palms for landscape use than it is to demand for fruit production (D. Young & W. Geissler pers. comm.).

Thus, date palm production in California and Arizona is an unusual agricultural commodity because it is one of the few crops that actually generates cash income (fruit production) to help defray production costs for 20–25 years until the palms attain a harvestable and saleable size (landscape use). For additional income during this time, growers can sell offshoots, small palms arising from the base of the mother palm that can be removed and planted to generate new palms.

Because date fruit production is dependent on named clones, for example 'Deglet Noor,' 'Medjool,' 'Zahidi' and 'Barhee,' growers can only propagate new palms vegetatively by tissue culture or by removing offshoots and planting them, which is the dominant method of propagation. Demand for offshoots is high and, depending on the variety, they can cost as much as US$100 to $300 each (D. Young & W. Geissler pers. comm.). This high value has prompted a rash of thefts of recently planted offshoots from fields in date growing regions of southern California and Arizona.

Propagation of date palms from offshoots frequently yields variable and disappointing results. A 50–80% survival rate for date palm offshoots is considered normal although some growers have reported successful establishment from as low as 10% to as high as 90% (D. Young & W. Geissler pers. comm.). After offshoots are removed from the mother palm, they are directly planted into the field where the new grove will be established. Furrow or flood irrigation is provided to maintain adequate soil moisture until the offshoots establish.

Successful establishment of date palm offshoots is dependent on regeneration of a new root system and leaf growth. Workers have cited many factors responsible for the success or failure of offshoots to establish and survive (Table 1). The purpose of our work was to observe the response of root systems and leaf growth of several date palm offshoots after removal and replanting and to determine which aspects might be critical in their successful establishment and in directing future research.

Materials and methods

A date grower in Indio, California removed 12 offshoots of *Phoenix dactylifera* 'Deglet Noor' from mother palms in a commercial date grove on 14 July 1999 and provided them for this study. The offshoots were positioned low on the mother palm at the soil line. Following standard industry procedures, skilled laborers dug soil away from the base of each offshoot and removed all leaves except for the 12 newest ones, which were then tied tightly together. During digging each offshoot's roots were cut to about 2–10 cm long.

Table 1. Factors cited in literature as responsible for the success or failure of offshoots to establish and survive.

Factor	Literature
variety (clone)	Drummond 1919; Nixon & Carpenter 1978; Zaid 1999
age/size	Albert 1926; Aldrich et al. 1945; Bader & Al-Yasiri 1986; Bader & Hummadi 1987; Cride, 1926; Dowson 1982; Drummond 1919; Hilgeman 1951; Nixon & Carpenter 1978, Reuveni et al. 1972; Toutain 1966; Wertheimer 1956; Zaid 1999
quantity of offshoots on mother palm	Aldrich et al. 1945
presence of roots	Albert 1926; Aldrich et al. 1945; Crider 1926; Furr 1966; Nixon & Carpenter, 1978; Wertheimer 1956
position on mother palm	Drummond 1919; Crider 1926; Dowson 1982; Gupta & Godara, 1984
leaf pruning	Albert 1926; Dowson 1982; Drummond 1919; Furr 1966; Reuveni et al. 1972; Zaid 1999
removal technique	Dowson 1982
planting technique	Albert 1926; Al-Mana et al. 1996
humidity	El-Hamady et al. 1992; Reuveni et al. 1972
temperature	Reuveni et al. 1972
soil moisture	Aldrich et al. 1945; Al-Mana et al. 1996; Bader & Al-Yasiri 1986; Furr 1966; Zaid 1999
plant growth regulators	Al-Mana et al. 1996; Bader & Al-Yasiri 1986; El Hodairi et al. 1992; Reuveni et al. 1972; Reuveni & Adato 1974
carbohydrate content	Reuveni et al. 1972; Reuveni & Adato 1974
time of year	Albert 1926; Bader & Hummadi 1987; Dowson 1982; Drummond 1919; Furr 1966; Reuveni et al. 1972; Zaid 1999

Using a sledgehammer, the workers drove a heavy, broad-bladed chisel between the offshoot and mother palm, cutting their connection. Once the offshoot was free, they cut the tied up leaves at a common point, removing about the upper half of their length, and cut off the remaining leaf bases of old or removed leaves, reducing the diameter of the offshoot base by 3–7 cm. At this point the offshoot had little or no soil around the roots and was ready for immediate planting in the field.

Prior to replanting, we recorded the height (distance) from base to the cut tip of the longest leaf, diameter of the base at its widest point, number of cut roots, number of leaves present, and the number of leaves removed at digging for each offshoot.

We planted the offshoots on the same day at the University of California, Riverside in UC potting mixture No. 2 (1 part peat moss and 1 part sand) in standard 50-liter (15 gallon) plastic nursery containers. We set them in the container so that the area where the roots originated from the stem was 20–25 cm below the potting mixture surface. Tomlinson (1990) termed this area the root initiation zone (RIZ). This depth is slightly shallower than that of the standard industry practice, which normally calls for planting the offshoot so that the area where roots originate from the stem is about 25–50 cm below the surface of the field soil. Planting depth is mostly dependent on the size of the offshoot; the larger the offshoot the deeper it is planted. Deeper

1. Co-author Dennis Pittenger holds offshoot No. 5, which had no root growth or leaf extension.

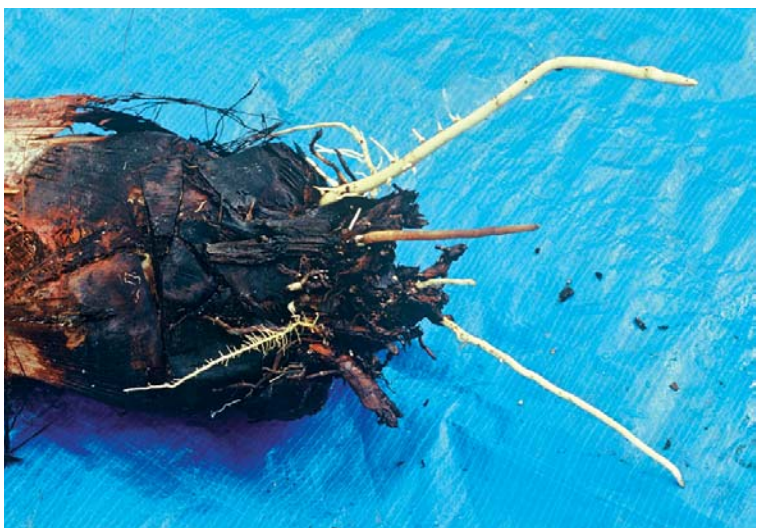
planting supports the offshoot in an upright position until new roots grow. Leaves remained tied up for the duration of the study. We placed the containers with potted offshoots in an unheated greenhouse for the duration of the 12-week study.

Immediately after planting we hand-irrigated the offshoots thoroughly to bring the potting mixture to container capacity. A drip irrigation system provided water for the duration of the study. Irrigation rates for each container were 2 liters per day for the first 2 weeks, then 2 liters 4 days a week for 6 weeks, then 2 liters 3 days a week for 2 weeks, and finally 2 liters 2 days a week. These schedules maintained the media at or near container capacity.

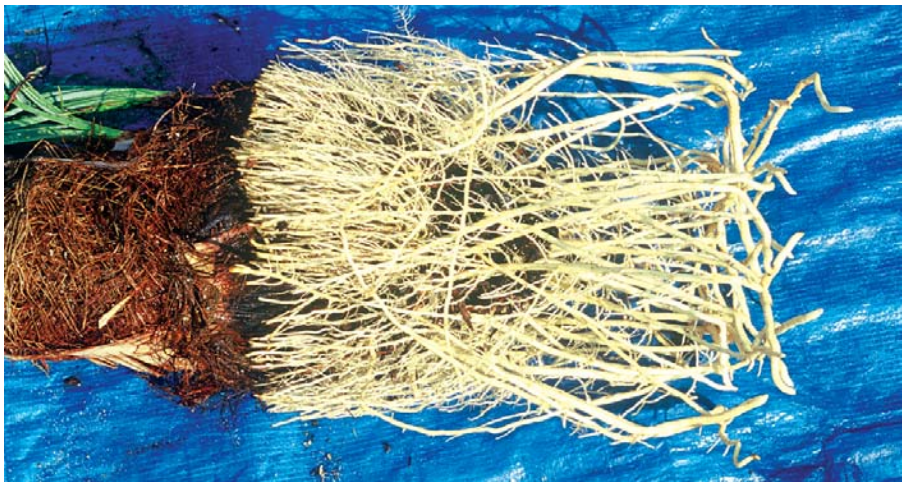
We continuously fertilized the offshoots through the irrigation system using a commercial fertilizer with N-P-K analysis of 21-5-20 at 300 ppm of N. During the study, night air temperatures in the greenhouse ranged from 15 to 21°C while day air temperatures ranged from 27 to over 38°C. Temperatures exceeded 38°C on 40 days with an estimated maximum temperature of 41°C. We recorded soil temperatures periodically using a thermometer placed 15 cm deep near the center of the container. Morning (0800–1000 hours) soil temperatures ranged from 23 to 25°C while afternoon (1300–1600 hours) temperatures ranged from 33 to 35°C.

Light levels inside and outside the greenhouse averaged 1000 μmol·m^{-2}·sec^{-1} and 1600 μmol·m^{-2}·sec^{-1} respectively, indicating that about 63% of available light was entering the greenhouse. We did not record relative humidity in the greenhouse but did use a Mee® fog/fine mist system for greenhouse cooling and humidity control for the first two weeks after planting. Pad and fan cooling was used throughout the duration of the study.

After 12 weeks we removed the offshoots from their containers and recorded their leaf extension (height). Using a high-pressure water jet to remove the potting mixture, we traced all new roots to their origin and recorded the number of new first order-roots originating from the stem and the number of new first-order roots originating from



2. Offshoot No. 10 had little root growth.



3. Offshoot No. 3 had significant root growth. Note mass of numerous secondary roots growing up to the surface. These may function for additional gas exchange in wet or saturated soils.

4. Offshoot No. 8 had a large, well developed RIZ broadly rounded proximally.

5. Offshoot No. 11 had a small, poorly developed RIZ lacking roots.

Table 2. Diameter at base, number of leaves (Lvs.), leaf extension (Ext.), number of cut roots, and number and origin of new roots of 12 date palm offshoots, University of California, Riverside, 1999.

Off-shoot	Base Diam. (cm)	No. Lvs.	Leaf Ext. (cm)	No. Cut Roots	Number and Origin of New Roots: Total	RIZ	Cut Face	Cut Roots
1	18.0	20	45.1	30	22	6	1	15
2	20.7	24	77.5	35	37	16	3	18
3	21.7	28	76.2	40	50	7	0	43
4	23.9	20	27.4	29	9	3	0	6
5	23.7	20	6.9	17	0	—	—	—
6	21.1	23	26.7	28	4	3	0	1
7	25.4	24	64.8	30	18	6	0	12
8	25.8	33	38.1	43	26	5	0	21
9	21.0	25	24.1	29	16	1	0	15
10	18.0	20	11.4	17	6	1	0	5
11	27.0	16	0.0	23	0	—	—	—
12	18.3	22	45.0	35	27	9	3	15

Table 3. Mean, median, and range of base diameter, number of leaves, leaf extension, and number of cut roots of 12 date palm offshoots, University of California, Riverside, 1999.

	Base Diameter (cm)	No. Leaves	Leaf Extension (cm)	No. Cut Roots
Mean	22.1	23.9	36.9	29.6
Median	21.7	22.5	32.8	29.5
Range	18–27	16–33	0–77.5	7–43

roots cut during removal from the mother palm. Of roots originating from the RIZ, we distinguished between those that originated from the uncut and undamaged surface and those that originated from the margin of the cut face (the flat, wounded surface made when the chisel cut the connection to the mother palm). We did not count second- and third-order roots. We cut the bases of six offshoots transversely and longitudinally to observe where and how new roots originated.

Results

We summarize the data for each offshoot in Tables 2 and 3. Mean base diameter was 22.1 cm with a range of 18–27 cm, while mean leaf extension was 36.9 cm with a range of 0–77.5 cm. All offshoots except one had leaf extension, some even before we planted them. Mean leaf number at planting was nearly 24 (23.9) with a range of 16–33 while the mean number of cut roots was nearly 30 (29.6) with a range of 17–43. Median values were nearly the same as the means except for the leaf extension, which was 32.8.

Of the 12 offshoots, Nos. 5 (Fig. 1) and 11 showed no root growth and little or no leaf extension. They were desiccated and we considered them to be dead. Nos. 4, 6 and 10 (Fig. 2) showed little root growth and relatively short leaf extension and had not established successfully but were not yet dead. The remaining offshoots had significant root growth and leaf extension (Fig. 3).

New roots were white and round and numbered 0–50 per offshoot with a mean of about 18 (17.9).

The longest new primary roots were 30–45 cm long and reached the bottom of the container where they were directed laterally. New roots originating from cut roots were numerous and about 3 or 4 mm in diameter, while those originating directly from the offshoot stem were fewer and larger at 4–7 mm in diameter.

Roots originating from cut roots often appeared a few centimeters from the point where the cut root attached to the stem. It was not possible to see their points of origin without removing the potting medium, leaf bases and other tissue on the surface of the stem. Gage (1901) and Broschat and Donselman (1990a) documented branching or resprouting of damaged or cut palm roots for related species, *Phoenix paludosa* Roxb. and *P. reclinata* Jacq. respectively, while Peebles (1936) documented the same phenomenon for the date palm. Secondary, tertiary, and quaternary roots were present and, in the most developed root systems, typically were growing toward the soil surface (Fig. 3). Tomlinson (1990) suggested that these upward growing and proliferating roots, characteristic of most palms naturally growing in or near wet or saturated soils, such as swamps, bogs, marshes, and ponds, function as sites for additional gas exchange.

All offshoots that survived and displayed good root development, such as Nos. 2, 3 (Fig. 3) and 8 (Fig. 4), had large, broadly rounded proximally, well developed and defined RIZs nearly around the entire perimeter although they were thin or briefly interrupted at the point of attachment with the mother palm (the cut face). These offshoots also had more roots when initially removed from the mother palm. In longitudinal section, these RIZs were broadly rounded at the proximal end where root initiation was concentrated and pointed at the distal end where shoot (leaf) growth originated. They were lighter in color than the surrounding tissue, bore ample root initials and roots, and decreased abruptly in diameter proximally but gradually in diameter distally.

In contrast, offshoots that had little or no root growth, such as No. 11 (Fig. 5), had small, poorly developed RIZs, which in longitudinal section tapered gradually at the distal and proximal ends. There were few root initials and little or no root growth.

In the 12 offshoots we observed a high ratio of new roots originating from cut roots compared to those originating from the RIZ. We summarize the mean, median, range and percent of new roots by origin (Table 4). A total of 215 new roots were produced, with a mean of nearly 18 (17.9), a median of 17, and a range of 0–50. Of those new roots, over two-thirds, 151 (70.2%), originated from cut roots while only slight more than one-fourth, 57 (26.5%), originated from the RIZ. Only 3.3% of new roots originated from the margin of the cut face, indicating the damage the RIZ sustained in this area during digging and separation from the mother palm. The mean, median, and range of new roots originating from cut roots are 15.1, 15, and 1–43 respectively; from the RIZ they are 5.7, 5.5, and 1–16 respectively; and from the margin of the cut face they are 0.7, 0, and 0–3 respectively.

Discussion

Although the study was not replicated, our observations indicate that shape and size of the RIZ, probably both functions of age but not necessarily of size of the offshoot, may affect the

Table 4. Mean, median, range and percent of new roots by origin of date palm offshoots, University of California, Riverside, 1999.

		Origin		
	Total	RIZ	Cut Face	Cut Roots
Number of Offshoots	12	10	10	10
Number of Roots	215	57	7	151
Percent	100	26.5	3.3	70.2
Mean	17.9	5.7	0.7	15.1
Median	17.0	5.5	0.0	15.0
Range	0–50	1–16	0–3	1–43

6. Offshoot No. 12 had new roots originating from cut roots only a few centimeters from the stem (lower left). Note presence of root initials and how original roots pushed out from the RIZ (bottom).

7. Cut root of offshoot No. 3 resprouted into three roots.

ability of the date palm offshoot to establish successfully. Offshoots with larger, well defined, and more broadly rounded RIZs produced more roots than those with smaller, poorly defined, and more slender RIZs. More importantly they had more roots when initially removed from the mother palm.

Wertheimer (1956) recognized the importance of the shape of the offshoot being round to establish successfully. Broschat and Donselman (1990b) linked diameter of the stem to development of the RIZ and regeneration of palm root systems in *Phoenix roebelinii* O'Brien and *Chamaedorea elegans* Mart. They reported that regeneration of root systems in these palms is dependent on the presence of the RIZ, and noted that the RIZ does not develop and become active until the stem has reached its maximum diameter and begins to elongate vertically.

We observed that the RIZ develops and becomes active at a much earlier stage in date palm offshoots, well before the offshoot stem attains its

maximum diameter and begins to elongate vertically. We suspect that the RIZ must attain a critical minimum size to ensure sufficient regeneration of a new root system but that this critical size is only loosely correlated with offshoot stem diameter. Certainly, this critical size is independent of the offshoot stem attaining its maximum diameter and then elongating vertically because none of the offshoots were anywhere near their maximum diameter yet all but three regenerated healthy, extensive root systems enabling them to establish successfully and quickly.

Most important was the ability of existing roots to resprout, sometimes with two to five additional roots each (Figs. 6, 7), after they were cut during removal from the mother palm. This discovery contrasts dramatically with Crider (1926), Dowson (1982) and Nixon and Carpenter (1978), who reported that most cut roots of date palm offshoots die, but it confirms the findings of Peebles (1936). The large percentage of new roots originating from cut roots also differs from Broschat and Donselman (1984, 1987, 1990a), who reported that roots of other palm species cut less than 15 cm from the stem rarely survive. Because over two-thirds of all the new roots grew from existing cut roots, offshoots possessing more roots when they are initially removed from the mother palm have a greater ability to regenerate a new root system. Such offshoots have larger, better defined, and more broadly rounded RIZs. Aldrich et al. (1945), Crider (1926), Furr (1966), Nixon and Carpenter (1978), Wertheimer (1956) and Zaid (1999) recognized the importance of a well developed root system prior to removal from the mother palm for successful establishment of offshoots but they did not associate it with the ability of existing roots to resprout and continue to grow once cut. Our work suggests that offshoots with 29 or more existing roots should establish successfully while those with 23 or fewer might die or take much longer to establish.

Offshoot size may be important for resprouting of cut roots, though. Al-Mana et al. (1996), Reuveni et al. (1972) and Reuveni and Adato (1974) concluded that the larger offshoots have more stored carbohydrates for energy for root growth, higher levels of root-promoting substances, and lower levels of root-inhibiting substances than smaller offshoots.

We believe previous investigators may have mistaken many resprouted cut roots for new roots originating from the RIZ. We found that cut roots often resprout within a few centimeters of the stem (Fig. 6) and might appear to be new roots from the RIZ. All roots must be traced to their origin to determine whether they originate from cut roots or the RIZ.

Offshoots with at least 30 cm leaf extension and 29 existing roots established most successfully. Those with at least 22 green leaves when removed from the mother plant generally grew more roots. Although some leaf extension occurred even before the offshoots were replanted, offshoots with at least 24 cm leaf extension are probably successfully established.

Conclusions

The RIZ must attain a critical minimum size and shape, both of which are unknown and directly immeasurable, for the offshoot to have enough existing roots to regenerate a sufficient number of new roots to establish and survive. The number of roots existing at the time an offshoot is removed from the mother palm appears to be most important, with 29 or more roots being optimal. Future work should be directed to determine which external indicators might be useful in determining when the offshoot and RIZ have attained the minimum size, optimal shape, and optimal number of roots for removal from the mother palm.

Protecting existing cut roots of date palm offshoots from damage when digging, transporting, and replanting is important because these are the sources of the majority of newly regenerated roots necessary for successful establishment. One might surmise that root pruning offshoots prior to removal from the mother palm would be beneficial. However, any newly sprouted roots would be susceptible to damage during the removal and replanting process. In all cases it is advisable to maintain a root ball at least 15 cm out from the perimeter of the offshoot to protect the existing cut roots and the RIZ.

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