Browning and Dieback of Distal Parts of Fruit-bearing Strands in Date Palms

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Abstract. The mineral concentration of bearing 'Mejhool' date palm (*Phoenix dactylifera* L.) trees was investigated with the objective of identifying the cause of browning and dieback of distal parts of the fruit-bearing strands. Tissue analyses of leaves, fruits, healthy and dead portions of fruit-bearing strands indicated that tissue browning and dieback appeared to be associated with a high concentration of certain mineral elements. A comparison of mineral concentration between healthy and dead tissue of the fruit-bearing strands showed no significant increase in K, Cu, B, Zn, and Na, but very high increases in the concentrations of P, Ca, Mg, S, Mn, and Fe. The levels of P, Ca, Mg, S, Mn, and Fe in the distal part of the fruit-bearing strand over a 3-year average were 5, 18, 12, 3, 11, and 2 times, respectively, higher than those in the healthy, proximal part of the strand. Mineral concentrations of leaves and mature fruits were determined for comparison with those in fruit-bearing strands.

For the past few decades the Coachella Valley, Southeast California, has experienced a decline in fruit quality of date palm. This has been documented by the gradual reduction in grades A (highest grade) and B (second highest) date fruits and a concomitant increase in grade C (low grade) fruits (Abdul-Baki et al., 1997). Our previous work focused on identifying management practices that would improve tree vigor, yield, and fruit quality of date palm (Abdul-Baki et al., 1998). Such identification could lead to improved cultural practices that may reverse the trend of decline in fruit quality observed in the past years in some Coachella Valley date orchards. The study covered over 560 ha of date palm orchards planted in 'Mejhool' and 'Deglet Noor', and included fruit-bearing trees of all ages, ranging from 10 to 65 years.

During the course of the study, we observed that the distal portions of the fruit-bearing bunches in 'Mejhool' became dry. While we consistently noted this phenomenon occurring with 'Mejhool' dates, we did not observe this occurring in 'Deglet Noor' fruit-

bearing bunches. We also noticed the same phenomenon in 'Zahidi' trees outside the experimental orchards under investigation. This phenomenon appeared every growing season, and was never investigated. The dry tissues eventually turned dark-brown (Fig. 1) and flowers borne on the affected tissues set fruits that aborted before maturity. Tissue desiccation and browning, first noticed between late April and early May, progressed from the strand's distal tip toward the central part, and continued into July. At that time, the dead portions of the distal ends of the strands measured 8 to 10 cm and bore no fruit.

Among the documented stresses common to the date palm orchards are 1) high temperature (over 43 °C) between April and October (Bygg, 1954, 1971); 2) high soil salinity with soil conductivity of saturation extracts reaching 10 millimhos/cm or higher (Armstrong, 1960); 3) high water table rising in some locations to 1 to 1.5 m below soil surface (Weeks, 1957); 4) excessive yearly applications of irrigation water between 4600 and 6200 mm (Furr and Armstrong, 1959, 1962); 5) sandy soils with organic content well below 1% (Knecht et al., 1980); and 6) high soil compaction and stratification that reduce root growth and movement of water and nutrients into the soil (Abdul-Baki et al., 1998). Although no information was found in the literature on this problem, it seemed reasonable to hypothesize that the browning and dieback could either be due to a pathogen, or some physiological disorder related to an imbalanced tissue nutrient, or to one or more environmental stresses that prevail in the Valley.

This study was undertaken to determine: 1) the mineral nutritional concentration of mature leaves, fruits and fruit-bearing strands in

Fig. 1. Fruit-bearing strands of 'Mejhool' date palm showing brown distal portions that lost the fruit.

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'Mejhool' date trees; and 2) differences in mineral nutritional concentration of healthy and dry, brown fruit-bearing strands that could be associated with tissue dieback.

Materials and Methods

In order to investigate the possibility of a pathogen as a casual agent of the dieback, we cultured healthy and brown-dead tissue on an agar medium in the laboratory and incubated them for 2 weeks. We found no signs of pathogen growth in the agar plates between the two tissues. It has been suggested that high-salt concentrations in the root zone can influence the uptake and transport of major ions such as K and Ca (Kuiper, 1984). Abdul-Baki et al. (1998) reported that the Coachella Valley could experience areas of high salinity. In an attempt to ascertain whether high ion levels in the irrigation water and soil may have been involved in the dieback of the distal strands, we analyzed six leaf samples and five fruit samples taken from individual trees.

We also determined the macro- and microelement concentration of the fully expanded fruit-bearing strands, whose average length in 'Mejhool' at full expansion reached about 50 cm. Samples were taken from three locations: the distal 7-cm tips that were dark-brown; the proximal 7-cm portions where the fruit-bearing strands were attached to the stalk (peduncle); and the 7-cm portions from the central part of the strand about halfway between the proximal and the distal portions. Both tissues from the proximal and central parts appeared healthy. Forty strands from the same tree were used per sample. We also conducted tissue analyses on mature fruits at harvest stage from the strands that exhibited tip dieback and browning. Each fruit sample consisted of 10 fruits taken randomly from fruit bunches that exhibited strand dieback and browning. Furthermore, leaf samples were taken from 1-year-old leaves that held the fruit bunches in their axils, following a sampling procedure described by Abdul-Baki et al. (1998). This approach of sampling fruit, leaf, and strand tissue from the same tree allowed comparisons of macro- and microelement concentrations among various tissues within the tree. Leaf tissues were analyzed over 2 years (1997–98). Fruits strands were sampled over a 3-year period and then analyzed.

Plant tissue mineral analysis was performed by inductively coupled plasma optical emission spectrometry (ICPOES). Oven-dried leaf, fruit, and fruit-bearing strands from the proximal, central, and distal portions were ground and stored in acid-washed vials. Total P, Ca, Mg, Na, K, Fe, Mn, and Zn were measured on nitric-perchloric acid digests by ICPOES. Boron was similarly analyzed, except that the oven-dried tissues were dry-ashed rather than digested by nitric-perchloric acid. Nitrogen was determined by standard micro-Kjeldahl method.

Macro- and microelement concentrations of 'Mejhool' date leaves and mature (ripe) fruits were analyzed using the SAS *t* test (SAS Institute Inc., 1998). Fruit-bearing strands were

Table 1. Macro- and microelement content of 'Mejhool' date leaves and mature (ripe) fruits.

Element	Leaves ²	Fruits ³	Leaf : fruit ratio
Macroelement ----- % of dry weight -----			
N	1.66 a ^x	0.56 b	3.0
P	0.12 a	0.08 b	1.5
K	0.74 a	0.86 b	0.9
Ca	0.65 a	0.06 b	10.8
Mg	0.20 a	0.09 b	2.2
Microelement ----- ppm -----			
Mn	62 a	8.4 b	7.4
Fe	167 a	28.8 b	5.8
Cu	10 a	12.5 a	0.8
B	12 a	15.1 b	0.8
Zn	13 a	11.2 a	1.2
Na	80 a	11.5 b	7.0

²Average of six samples of 16 pinnaes each.

³Average of five samples.

^xSignificant differences between leaf and fruit tissue were tested using SAS *t* test procedure (SAS Institute, 1998) and are indicated by a different letter ($P \leq 0.05$).

analyzed using three replicates with heterogeneous variance within strand location, and were modeled utilizing the group options of the Proc Mix repeated statement (SAS Institute Inc., 1999). One-way analysis of variance was used to compare strand location with each nutrient.

Results and Discussion

Analyses revealed large differences in both the macro- and microelement levels between leaf and fruit tissue (Table 1). All macro- and microelements, except for K, Cu, B, and Zn, were significantly higher in leaves than in fruits. The largest difference in element concentration between leaves and fruits was in Ca, followed by Mn and Na. The concentrations of Fe and N were 5.8 and 3.0 times higher in the leaves than in the fruits, respectively.

Interestingly, our results on macroelement levels in leaves are in close agreement with those previously reported by Reuther (1948) on the date cultivar Deglet Noor from Coachella Valley orchards, and on four date cultivars grown in Saudi Arabia (Abo Hassan and Bacha, 1982). However, our results were 40% to 50% lower than those reported by Shawki and Mougheith (1974) on five date palm cultivars in Egypt. One possibility is that these nutritional differences could be related to differences in soil fertility among the various locations, although no soil fertility data were provided in these reports.

Published information on mineral concentration of fruit from mature date trees at the harvest stage have been limited to one report on 'Deglet Noor'. Haas (1935) reported P, K, Ca, and Mg levels in ripe fruits to be 0.23%, 1.19%, 0.08%, and 0.07% of fruit dry weight, respectively. No data on N concentration were reported. Our data (Table 1) on macroelement concentration in mature 'Mejhool' fruits are in reasonable agreement, except for P, with those reported by Haas (1935) on 'Deglet Noor' fruits. Of interest are the low Na and high K in fruits, which are important nutritional properties in foods. As for the microelements, to our knowledge this is the first report on microelement levels in date leaf and fruit tissues.

With the exception of K, both macro- and micronutrient concentrations including Na in the fruit-bearing strand tissue increased with the strand distance from proximal part to distal part (Table 2). Very high accumulations of P, Ca, Mg, S, Mn, Fe, Cu, B, and Zn were found in the distal part, and their concentrations were 4.8, 19, 12, 2.9, 11, 1.6, 2.4, 7.7, and 5.4 times higher than those in the proximal part, respectively. However, only the Ca, Mg, S, Mn, and Fe concentrations in the distal part were detected as statistically significantly ($P \leq 0.05$) higher than that in the proximal parts. Between the proximal and central parts, no significant differences were found in both macro- and micronutrient concentrations, except S.

At present, there are no data available in the literature on optimal levels of macro- and microelements of date-fruit strand. However, we feel that the levels found in date leaves, fruits, proximal and central but not distal parts of the fruit strand are possibly in an appropriate range or close to optimal since the tissues appeared healthy. Large accumulation of macro- and microelements in certain parts of the fruit-bearing strands may lead to physiological disorders and toxicities, particularly with respect to the concentrations of Mg, and B in the distal part of the strand (Gupta, 1993; Robinson, 1986). The detected high Mg and B concentrations in the distal part of fruit-bearing strands might be involved in the browning and death of the tissue. Although data are lacking for Mg or B toxicity levels in date palm, Robinson (1986) reported that B levels of greater than 80 or 100 ppm are either excessive or toxic in such tropical trees as bananas or avocado, respectively. Other fruit-bearing trees, such as apricot, cherries, and citrus, have similar B toxicity levels (Robinson, 1986). Our reported level of B in the distal part of the strand clearly exceeds these levels (Table 2).

As to Mg levels, Robinson (1986) reported that levels greater than 1.1% to 1.2% dry weight can be toxic or excessive in many fruit-bearing trees, including apricot, avocado, cherries, and citrus. Our measured levels in the healthy proximal and central portions are within or reasonably close to this range (Table 2). However, the Mg level in the distal part was

Table 2. Means difference, standard error for macro- and microelement content of proximal, central and distal parts of fruit bearing strands in 'Mejhool'.

Elements	Strands location	Mean ^z	Standard error
Macroelement		%	
P	Distal	0.38	0.02 a
P	Central	0.11	0.03 b
P	Proximal	0.08	0.02 b
K	Distal	1.97	0.16 a
K	Central	2.79	0.42 a
K	Proximal	2.38	0.42 a
Ca	Distal	2.27	0.27 a
Ca	Central	0.17	0.03 b
Ca	Proximal	0.12	0.03 b
Mg	Distal	6.67	1.24 a
Mg	Central	1.12	0.34 ab
Mg	Proximal	0.56	0.34 b
S	Distal	0.60	0.02 a
S	Central	0.32	0.02 b
S	Proximal	0.21	0.02 c
Microelement		ppm	
Mn	Distal	49.27	3.55 a
Mn	Central	9.87	3.55 b
Mn	Proximal	4.57	0.46 b
Fe	Distal	92.90	8.50 a
Fe	Central	82.17	8.50 ab
Fe	Proximal	58.33	2.97 a
Cu	Distal	10.97	2.25 a
Cu	Central	4.47	2.25 a
Cu	Proximal	4.60	2.25 a
B	Distal	276.43	133.35 a
B	Central	37.53	26.30 a
B	Proximal	35.67	26.30 a
Zn	Distal	62.57	10.96 a
Zn	Central	12.10	3.08 a
Zn	Proximal	11.53	3.08 a
Na	Distal	203.57	111.94 a
Na	Central	186.20	111.94 a
Na	Proximal	171.27	111.94 a

^zMean values with different letters within a strands location are significantly different at $P \leq 0.05$ as determined by the Proc Mixed models procedure of SAS (1999).

found as 6.67% of dry weight, much higher than these toxic or excessive levels. Thus, it appears that high levels of Mg, and perhaps B, may be a factor involved in the dieback of the distal portion of the fruit-bearing strand in date palm.

If we exclude the distal part of the fruit strand because of the high levels of Ca, Mg, and B, and compare the mineral concentration of the proximal and central parts of the strands with those of leaves and fruits, we observe the following: The concentrations of P, Mg, and Zn among all the tissues are within a close range; K is higher in strands than in leaves and fruits; Mn and Fe are highest in strands; and Na is almost lacking in fruits.

It is unclear from our research as to the exact mechanism for maintaining low Na level in the fruits. These low Na levels are especially noteworthy considering not only the Na levels in irrigation water and soil (Abdul-Baki et al., 1998), but also the Na levels in the nearby tissue, such as leaves and fruit-bearing strands (Table 2). On a speculative note, it may be that a Na/H antiport mechanism may be operating

on the plasma membrane of the fruit cells. Support for this contention, as far as the literature is concerned, is the finding of a Na/H antiporter, which has been suggested to function in conjunction with a membrane-bound ATPase to remove Na from the cell interior in a number of plants (Apse et al., 1999; Blumwald and Poole, 1985; Gabarino and DuPont, 1988; Wilson and Shannon, 1995). Future work will investigate the possible involvement of a Na/H antiport mechanism in the membranes of date fruit tissue. Additionally, the finding that Ca, Mg, and B accumulate in the distal parts of the fruit strands warrants further investigation. The distal part of the fruit-bearing strand appears to serve as a sink that holds the elements and maintains them at a low level in the fruit.

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