used without burn. When spray must be blown through low canopy foliage to reach upper canopy foliage, however, the low canopy foliage often receives excessive amounts of the spray ingredients. It also appears that it might be difficult to apply macronutrients in sufficient quantities to cause significant increases in leaf concentration by trunk injection without causing leaf damage. More work is required to find suitable combinations of anions and cations at suitable concentrations for rapid correction of Mg deficiency by trunk injection. The latter method of application of micronutrients and pesticides has been successful (6, 7) and is now being used commercially on 250,000 pear trees in California (4) for control of pear decline.

Literature Cited

1. Barr, A. J., J. H. Goodnight, J. P, Sall, and J. T. Helwig. 1976. A user's guide to SAS '76. Sparks Press, Raleigh, N.C.
2. Emino, E. R., J. B. Storey, and M. W. Smith. 1979. Enhanced zinc uptake by container-grown shrubs. *HortScience* (in press).
3. Jones, J. B., Jr. 1976. Elemental analysis of biological substances by direct-reading spark emission spectroscopy. *Amer. Lab.* 8:15-22.
4. Reil, W. O. 1979. Pressure-injecting chemicals into trees. *Calif.* Agr. 29(6):16-19.
5. Storey, J. B., M. W. Smith, and P. Westfall. 1974. Zinc nitrate opens new frontiers on rosette control. *Pecan Quart.* 8(1):9-10.
6. Wilson, C. L., R. A. Spotts, and C. R. Semer, IV. 1977. New injection equipment and a new fungicide for Dutch elm disease control. *Plant Dis. Rptr.* 61: 694-698.
7. Worley, R. E. 1971. Pecan leaf analysis service summary. 1969. *Ga. Agr. Expt. Sta. Res. Rpt.* 110.
8. ————, R. L. Carter, and A. W. Johnson. 1975. Effect of magnesium sources and rates on correction of acute Mg deficiency of pecan. *J. Amer. Soc. Hort. Sci.* 100:487-490.
9. ————, R. H. Littrell, and S. G. Polles. 1976. Pressure trunk injection promising for pecan and other trees. *HortScience* 11:590-591.

HortScience 15(2):182–184. 1980.

Tree Implanted Zinc-bentonite Paste as a Source of Slow-release Zinc for 'Delmas' Pecan[1]

A. Banin, J. Navrot, and Y. Ron[2,3]
Department of Soil and Water Science, Faculty of Agriculture, The Hebrew University, Rehovot, Israel

Additional index words. mineral nutrition, *Carya illinoensis*

Abstract. **Zinc was supplied to trees of 'Delmas' pecan (*Carya illinoensis* (Wang. K. Koch) by means of Zn saturated bentonite paste implanted into the limbs. Five treatments, 0, 56, 107, 133 and 213 mg Zn per limb in the form of Zn-bentonite paste were applied to 5 years-old trees in a commercial plantation at the beginning of the growing season. Almost all the Zn was released during growth into the transpiration stream and increased the Zn-leaf concentration. No visual damage in treated limbs was caused by implantation *per se,* although the highest rate of Zn reduced leaf growth somewhat. The optimal dose of Zn was 107 mg/limb equivalent to only about 2-3% of the Zn usually supplied by commercial spraying.**

Extreme Zn deficiency in pecan causes the symptomatic "rosette" development of twigs and reduces nut yield. Therefore, the addition of Zn is an essential part of the economical pecan growing process in many areas (3, 4, 11, 12). However, in plantations grown in calcareous soils, zinc deficiencies are quite difficult to correct. The customary method in Israel is to apply 3 to 5 foliar sprays early in the spring growth season (April-May), generally using a mixture of 0.5% $ZnSO_4$ and 0.5% urea. Use of other forms of Zn, such as chelates (6), is very limited for economic reasons. Spray application to fully developed pecan trees is time consuming and expensive. Moreover, zinc uptake from foliar spray is sometimes erratic and considerable differences in Zn-leaf concentration between treated trees, are found (10).

Trunk injection has been attempted as a means to supply nutrient elements to various trees. Phosphorus has been injected into pecans (5), iron into avocado (8) and zinc into apple (7) and pecan (13). In all these cases, aqueous solutions of the element(s) were pressure-injected into the trunk or limb(s) of trees. Advantages of an effective direct injection system of nutrients to trees are numerous (13) and include biological, technical and economic benefits: a) Movement of added elements in the tree is rapid and deficiencies are quickly corrected, b) quantities used are small compared with foliar or soil applications, thus reducing cost and minimizing air, soil and crop pollution hazards and c) equipment operation costs are relatively low. However, there are some disadvantages to the solution injection method, mainly due to a rapid rise in the concentration of the element injected in the leaves. Localized and temporarily high concentrations of the injected element may cause tissue damage due to either osmotic effects or specificity effects or both. Use of low solution concentration necessitates either long injection periods or frequent injections.

An ideal micronutrient supply system would be a concentrate of the nutrient element maintained at a "slowly available" state, placed in the trunk or limb and slowly released into the transpiration stream of the tree. A novel, recently developed fertilizer carrier for micronutrients, metal-bentonite (1), might be such a source of slow release micronutrients. Previous experiments with metal-bentonite (2, 9) showed that in soil applications to annual plants, was more effective than salts and slightly less effective than chelates in supplying Zn to tomato and bean plants. The present study reports some preliminary but promising results on the use of slow release bentonite-adsorbed zinc for limb and trunk implantation into young pecan trees.

Young (5-years-old) 'Delmas' pecan trees in a commercial plantation, Kibbutz Shoval, Beersheva region, Israel, were used for this study. The soil is aeolian in origin and of loamy to silty loam texture containing 16 to 22% $CaCO_3$; and the pH of the saturated soil paste is 7.2 to 7.9.

Zinc-bentonite paste used as Zn-carrier was prepared by the "quantitative ion exchange method" (1), the clay concentration in the paste was 39.5% and it contained 8.4 mg Zn/g paste, of which 5.5% and 93.8% were in soluble and exchangeable forms, respectively. Ten trees were used for the experiment. Each treatment was applied to 2 similar (15-20 cm in circumference) limbs in each of 2 trees, giving 4 replications. In the base of each treated limb, 2 to 5 holes, with diameters of 1.2 or 1.9 cm were drilled, containing either 3 or 6 cm^3 of paste,

---

[1] Received for publication July 7, 1979. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper must therefore be hereby marked *advertisement* solely to indicate this fact.

[2] Professor of Soil Science, Senior Soil Chemist and Graduate Student, respectively.

[3] This research was supported in part by the Ministry of Agriculture of Israel and by the Histadruth. The help of the workers in the pecan plantation in Shoval is gratefully acknowledged.

Table 1. Monthly averages of area and dry weight of pecan leaves (per leaf basis).

Application rate^{z} (mg Zn/limb)	May 7		June 4		July 5		Sampling date August 6		September 4		October 8		November 11	
	Area (cm^2)	Avg wt (g)	Area (cm^2)	Avg wt (g)	Area (cm^2)	Avg wt (g)	Area (cm^2)	Avg wt (g)	Area (cm^2)	Avg wt (g)	Area (cm^2)	Avg wt (g)	Area (cm^2)	Avg wt (g)
(T_1) 0	154	0.95	304	2.8	416	3.5	493	3.7	482	4.6	419	4.9	544	5.4
(T_2) 53	181	0.90	288	2.6	433	3.5	496	4.5	533	6.5	494	7.2	481	6.8
(T_3) 107	178	1.19	298	3.2	493	3.0	612	5.5	549	7.5	525	7.2	566	8.3
(T_4) 133	173	0.88	265	3.1	473	3.5	586	4.7	451	5.3	388	5.1	368	4.8
(T_5) 213	175	0.91	275	3.1	358	3.6	428	3.9	342	4.3	331	4.5	470	5.1

^{z}Bentonite placement on April 23.

respectively. The bentonite paste was introduced into the holes, which were then plugged with a plastic stopper. The following treatments of Zn-bentonite were applied: 0, 53, 107, 133 and 213 mg per limb, respectively. Date of application was April 23, 1977. Other trees in the plantation received the commercial foliar sprays 4 times during the season. It is estimated that each tree received about 35 to 50 g of elemental Zn by the commercial treatment. All leaves on each of the treated limbs were counted monthly, beginning 2 weeks after the Zn-bentonite placement. Leaf samples (either third or fourth from the terminal bud) were collected for determination of leaf area, fresh and dry weight, and Zn concentration. These data were used in the computation of monthly biomass production and Zn-uptake per limb. Zn concentration in leaves was determined after wet digestion by atomic absorption spectroscopy.

No visual damage to whole trees or to treated limbs was observed as a result of the drilling or clay placement. The bentonite paste in the holes was moist during the whole growth period and could be easily sampled in November, at its termination, showing that callus formation was slow.

Effects of the Zn treatment on leaf size (area and weight) were observed despite the lack of visual Zn deficiency symptoms (Table 1). Treatment 3 (107 mg Zn/limb) appeared to be optimal, whereas treatments 4 and 5 (133 and 213 mg Zn/limb), respectively, apparently suffered from the higher Zn application, and showed reduced growth rate. The effect of the Zn-bentonite implantation upon zinc concentration in the leaves was most evident during the 2- to 6-week period after application (Fig. 1). With time, zinc concentration in the leaves decreased in all the treatments and much lower differences in leaf-Zn between the various treatments were observed after July. This indicates that most of the Zn was released from the clay during a period of up to 6 weeks, and a very limited translocation of Zn, took place in the tree between old and young leaves.

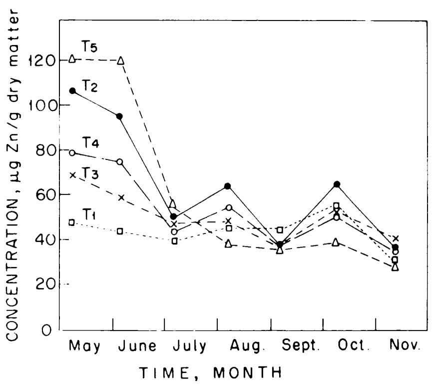

Fig. 1. Zinc concentration (µg Zn/g dry plant material) of pecan leaves (refer Table 1 for treatments).

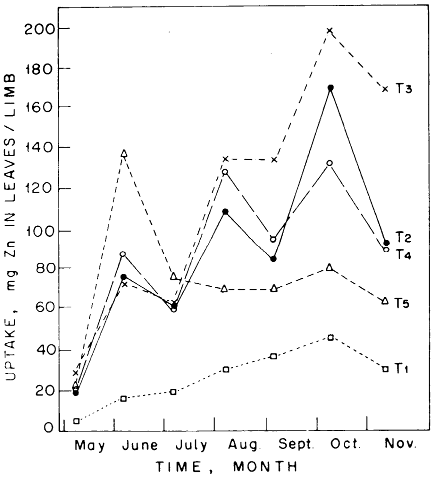

Fig. 2. Zn-uptake by leaves in treated limbs of pecan (mg Zn in leaves/limb) (refer Table 1 for treatments).

The cumulative Zn-uptake [(leaf-Zn concentration) x (mean dry matter weight per leaf) x (number of leaves on each limb)] from the 4 replicates for each treatment, demonstrate the effectiveness of Zn-bentonite as a new Zn-carrier for pecan (Fig. 2). Apparently toxic effects of excess Zn in treatments 4 and 5 reduced leaf growth and biomass production and resulted in decreased Zn-uptake, despite increased concentration in the leaves. The highest Zn-uptake was obtained in mid-September by implantation of 107 mg Zn-bentonite paste. This treatment thus appears again to be the optimal one. At the end of the growth period, residues of the bentonite material were removed from the holes in the trees and the residual Zn content was measured. No more than 15 to 18% of the applied Zn was still adsorbed onto the clay, with the exception of the highest application rate (treatment no. 5) where 42% of the Zn remained. This shows that Zn was effectively taken up from Zn-bentonite paste by the transpiration stream and into the leaves in the cases where sufficient growth took place.

The present experiment was limited in extent, therefore the results obtained are considered as preliminary in nature; however, they encourage us to conduct further experiments. The low amounts of Zn applied by this method are of particular interest; the optimal treatment supplied about 100 mg Zn per limb in our experiment. Equivalent application rate for the whole tree would be about 1 g Zn for young trees and 2 to 3 g Zn for fully developed trees. These amounts are only 2 to 3% of the Zn applied per tree in commercial spraying. In addition, the proposed method of implantation is easy to perform, appears to cause no damage to the tree and can replace multiple spray operations by a single implantation during the season. However, full economic evaluation of the suggested method requires further experimentation, development, and optimization of the techniques.

Literature Cited

1. Banin, A. 1975. "Clay attached micronutrients", U.S. Patent No. 3,902,886.
2. __________ and J. Navrot. 1976. Comparison of modified montmorillonite to salts and chelates as carrier for micronutrients for plants. I. Supply of copper, zinc and manganese. *Agron. J.* 68:353-358.
3. Blackman, G. H. and R. H. Sharpe. 1961. Pecan growing in Florida. *Florida Agr. Expt. Sta. Bul.* 437:1-71.
4. Brooks, O. L. 1964. Yield and growth response of 'Stuart' pecan trees to zinc sulphate and nitrogen. *Georgia Agr. Expt. Sta. Cir.* (N.S.) 40.
5. Hammer, H. E. 1949. Trace studies on the uptake and movement of phosphorus in pecan tree nutrition. *Proc. S.E. Pecan Growers Assoc.* 42:69-70. (Abst.)
6. Harper, R. E. 1960. A chelate for controlling zinc deficiency in pecan trees. New Mexico Agr. Expt. Sta. Res. Rpt. 36.

7. Hoffman, M. and R. S. Samish. 1966. The control of zinc deficiency in apple. *Israel J. Agr. Res.* 16(3):105-113.
8. Kadman, A. and A. Cohen. 1974. A rapid method for curing chlorotic avocado trees. *Yearb. Calif. Avocado Soc.* 56: 159-165.
9. Navrot, J. and A. Banin. 1976. Comparison of modified montmorillonite to salts and chelates as carrier for micronutrients for plants. II. Supply of iron. *Agron. J.* 68:358-361.
10. Sharpe, R. H. and N. Gammon, Jr. 1961. Source of error in foliar analysis of pecans. *Proc. Amer. Soc. Hort. Sci.* 58: 120-124.
11. Storey, J. B. and W. B. Anderson. 1970. Pecan zinc nutrition research. Texas Agr. Expt. Sta. Prog. Rpt. 2710.
12. Worley, R. E., S. A. Harmon, and R. L. Carter. 1972. Effect of zinc sources and methods of application on yield and leaf mineral concentration of pecan. *J. Amer. Soc. Hort. Sci.* 97:364-369.
13. ———— and S. G. Polles. 1976. Pressure trunk injection promising for pecan and other trees. *HortScience* 11:590-591.

HortScience 15(2):184–185. 1980.

Xenia and Metaxenia in Pistachio[1]

Julian C. Crane and Ben T. Iwakiri
Department of Pomology, University of California, Davis, CA 95616

Additional index words. pollination, *Pistacia vera, P. atlantica*

Abstract. **Pollen from 5 different sources did not alter fruit size or time of maturity of 'Kerman' pistachio (*Pistacia vera* L.). Degree of shell (endocarp) dehiscence was modified with some pollen sources but was found to be related directly to kernel development rather than to type of pollen. Thus, there were no manifestations of metaxenia. Xenia, as exhibited by reduced kernel length and dry weight, did occur, however, following the use of *P. atlantica* and hybrid pollen.**

The pistachio, *Pistacia vera,* is one of few plants in which xenia and metaxenia have been observed (8, 9, 12). Peebles and Hope (8), working with the 'Red Aleppo' and 'Trabonella' cultivars as seed parents, reported delayed maturity, increased fruit length, and increased shell (endocarp) splitting, depending upon the pollen applied. Whitehouse et al. (12), working with the 'Sfax', 'Bronte', 'Red Aleppo', and 'Trabonella' cultivars as seed parents, also found certain kinds of pollen to bring about delayed maturity. Pollen of *P. vera* produced more nuts with split shells and nuts with larger kernels than pollen of 4 other *Pistacia* species. Pontikis (9), on the other hand, working with an unspecified Greek cultivar, noted hastening of maturity and increased kernel weight, depending upon pollen source. Thus, these studies have indicated that both the seed and the tissues composing the fruit may be modified by the pollinizer, responses defined by Swingle (11) as xenia and metaxenia, respectively.

Interspecific hybridization readily occurs among the various species of *Pistacia*, e.g. *P. vera, P. atlantica, P. terebinthus, P. Palaestina, P. integerrima, P. chinensis,* etc. (5, 8, 12). The fact that most species bloom ahead of *P. vera* enables the collection, preparation and storage of their pollen for use later in pollinating the pistachio.

The pistachio is dioecious and staminate trees are strategically located among pistillate trees in the orchard to provide pollen at the time pistillate flowers are receptive. The apetalous flowers do not attract insects and pollen dispersal is by wind. The degree to which pollination occurs, therefore, is dependent upon prevailing weather conditions. Research is being conducted toward the collection and storage of pollen for use in supplementing natural pollination. Also being explored is the possibility of developing a completely controlled artificial pollination procedure, in which pollen would be collected from staminate trees (not necessarily only those growing within the orchard), stored, and applied mechanically with dusting or spraying equipment. Such a procedure could eliminate use of valuable orchard space by staminate trees that serve only as sources of pollen. Should these procedures prove to be practical, it would be desirable to know the xenia and metaxenia responses, if any, of 'Kerman' (currently the only pistillate cultivar being grown commercially in California) to the various types of pollen available. This paper presents the results of an initial study to determine the response of 'Kerman' to 5 different pollen sources.

Male inflorescences were collected prior to dehiscence in late March from a *P. atlantica* and a hybrid *(P. vera* × *P. atlantica)* tree in a commercial orchard at Elk Grove. The inflorescences, as well as those collected later from 'Aegina B', 'Ask', and 'Peters' (all *P. vera*) trees at Winters, were spread on paper at 22°C in the laboratory. The next day the pollen was separated from the inflorescences by screening and stored in glass vials stoppered with cotton plugs in a freezer at −15°C. Previous study had indicated the value of low temperature for preserving *Pistacia* pollen viability (4).

Five 9-year-old 'Kerman' trees growing at the Wolfskill Experimental Orchards, Winters, were selected on the basis of their relatively large numbers of inflorescence buds. Twelve branches, each supporting 3-5 inflorescence buds, were selected on each tree. On April 3, before anthesis, these branches were enclosed in bags made of tightly woven, white cotton gabardine, material that had proven satisfactory in walnut breeding operations (10). The bags were eventually removed from the branches on April 24, several days after anthesis of the last 'Kerman' flowers and when pollen had ceased shedding primarily from 'Peters' trees in the vicinity.

Each of the 5 different kinds of pollen was applied to the inflorescences on 2 branches on each of the 5 trees. Pollen application was made in the early, windless mornings of April 13, 16, 18, and 20. Flowers were pollinated by daubing them with the cotton plugs covered with pollen. Two of the bagged branches on each tree served as unpollinated controls. Bags on these branches were removed briefly and replaced each morning that pollen was applied to the test flowers.

Average number of flowers per inflorescence was determined by counting the number of flowers in each of 25 inflorescences picked at random from the 5 experimental trees. The number of nuts harvested per cluster was used in determining the approximate percentage of fruit set resulting from a particular kind of pollen.

Nuts were harvested at maturity, as judged by the time at which the hull separated easily from the shell (3). Length and cheek diameter of each fruit were measured with a vernier caliper and, after hull removal in a hulling machine, the nuts were dried in a dehydrator. Length and cheek diameter measurements of the kernels were made, as well as dry weight determinations.

Less than 1% of the flowers on 4 bagged but unpollinated branches set fruits, all of which were parthenocarpic.

---

[1] Received for publication September 25, 1979.

The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper must therefore be hereby marked *advertisement* solely to indicate this fact.