rounding the fruit. Change is relatively quick and therefore any atmospheric temperature change will affect the avocado fruit. In another test, where the rate of heating and the rate of cooling in the avocado fruit were measured, the fruit temperature went from 41°F to 56°F within fifteen minutes in an atmosphere of around 67°F. In a measurement of the cooling rate, individual fruit temperatures dropped from 67°F to about 48°F in 45 minutes. Within the next two hours the fruit temperature had dropped to about 42°F in a cold box reading about 41°F.

Conclusions concerning the sensitivity of avocado fruit include the observation that the skin is subject to more temperature changes, and more rapid changes, than the interior of the fruit. On the other hand, the lag of the interior temperature is slight, and for all practical purposes, the entire fruit can be considered as being influenced by temperature changes. This test provides a basis for further studies into temperature effects on fruit quality. Tests are now under way to determine fruit reaction to a continuous high temperature, a continuous low temperature, or a temperature fluctuating between high and low.

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# IRON ADDITIVES Influence Plant Reactions To 2,4-D Concentrations

**Tests show that wheat and barley can withstand higher concentrations of 2,4-D when an iron additive is included in the spray solution—indicating the possibility of obtaining increased growth of cereals over a broader range of 2,4-D concentrations and increased efficiency of broad-leaved weed control.**

R. C. HUFFAKER · A. V. SARQUIS · M. AKASHA · M. D. MILLER

PREVIOUS UNIVERSITY RESEARCH has shown that inorganic and organic additives can markedly influence the stimulatory, inhibitory, and herbicidal effects of 2,4-D on intact plants. A metal, a chelated metal, or a chelating agent used in the 2,4-D spray increased the range of concentrations by 200-fold, resulting in increased growth of beans. Ammonium and phosphate ions increase, while iron, copper and zinc reportedly decrease the herbicidal effects of 2,4-D.

The study reported here has shown that the simultaneous application of an iron chelate, FeEDDHA, with 2,4-D can have one of several effects: it can increase the growth stimulatory range of 2,4-D concentrations on intact bean plants; decrease the injurious effects; have no effect; or increase the lethal effect of 2,4-D. The range of effects depended on the specific concentration of 2,4-D and were proportional to the concentration of FeEDDHA. At a predetermined growth-inhibitory concentration of 2,4-D, each molecule of FeEDDHA reversed the inhibitory effect of 100,000 molecules of 2,4-D on shoot length; however, shoot dry weight was only partially recovered. Shoot length measurements were not sufficient to determine recovery from injury by 2,4-D. Shoot length measurements were found earlier to be least satisfactory in determining growth stimulation by 2,4-D. Shoot dry weight was completely recovered only when the concentration of FeEDDHA was 100-fold greater than 2,4-D. The recovery effect attributed to FeEDDHA was noticeable throughout a concentration gradient of $10^{-9}$ to $10^{-2}$ M FeEDDHA. Restoration of dry weight was a more realistic measure of recovery than was shoot length, and much higher concentrations of an additive were required for recovery of the weight than the shoot length.

## Inorganic ions

Inorganic ions as well as metal chelates and chelating agents are effective in preventing injury by 2,4-D. There are important aftereffects, however, which must be considered. $Na_2SO_4$ at $2.7 \times 10^{-2}$M caused a yellowing of the leaves about four to five days after treatment, whereas plants treated with FeEDDHA at $2.7 \times 10^{-2}$M remained green and healthy throughout the time of the growth periods. Glutamic acid and aspartic acid did not influence the injury induced by 2,4-D. Other workers have shown that nitrogenous compounds tend to increase the toxicity of 2,4-D.

The results showed that the interaction of 2,4-D and FeEDDHA was greatly dependent on the concentration of 2,4-D. As the concentrations of 2,4-D were increased from the growth-inhibitory to the lethal, the effect of FeEDDHA was progressively changed from that of protecting against 2,4-D injury, to no effect at all to increasing the toxicity of the 2,4-D. This is also in agreement with other workers who reported that a high concentration of chelating agent increased the growth-inhibitory effect of a high concentration of auxin on wheat root and coleoptile sections.

Other workers have reported that Fe can decrease the lethal effect of 2,4-D. Therefore, it is important to realize that Fe can protect from, or add to, the lethality of 2,4-D depending on the concentration of 2,4-D employed. The results also showed that the effects obtained with FeEDDHA greatly depend on its concentration. At $2 \times 10^{-3}$M 2,4-D, very low concentrations of FeEDDHA, $10^{-9}$ to $10^{-4}$ M, delayed the plants from death for several days, after which the protective effect was lost. At $10^{-3}$ and $10^{-2}$ M, FeEDDHA completely protected the plants from death. Low concentrations may be effective only for several days due possibly to metabolism or breakdown of the FeEDDHA due to light. The breakdown products may not be effective as protectants against 2,4-D injury. A like effect has been reported with versenol. An injection of versenol prevented epinasty (leaf curl) due to 2,4-D in tomato plants for only a few hours, after which epinasty occurred.

### Mechanism

The mechanism involved in the ability of an Fe additive to either protect from, or add to, the lethality of 2,4-D is probably quite complicated. Earlier work had shown that an Fe additive can behave as a protective agent whether applied 24 hours before, simultaneously with, or 24 hours after the 2,4-D. This strongly indicated that the Fe additive primarily influenced the action of 2,4-D within the plant rather than affecting the absorption of 2,4-D through the leaf surface. FeEDDHA did not seem to cause any breakdown of 2,4-D since the 2,4-D was active again after the protective effects of low concentrations of FeEDDHA disappeared.

Applications of 2,4-D to barley and wheat have resulted in increased yields of grain. Data from these tests showed that wheat and barley can withstand higher concentrations of 2,4-D when an Fe additive is included in the spray solution. Since barley and wheat are much less sensitive to 2,4-D than broad-leaved weeds, it is possible that the presence of an Fe chelate can increase the stimulatory range of 2,4-D concentrations for barley and wheat and bring about increased efficiency of broad-leaved weed control.

Application of modifying agents in the chelated form could become important in future field applications of growth regulators since formation of copious precipitates is prevented when commercial water, usually high in salt content, must be used for sprays.

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# HEAT CONTROLS NEMATODES IN SWEET POTATO ROOTS

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**Studies in San Bernardino County showed that 95 to 100% of slips grown from sweet potato roots that were heavily infested with root-knot nematodes also became contaminated. A simple, effective treatment consisting of dry heat—first, at 60° to 100°F for six to eight hours, then at 108° to 110°F for 24 hours—successfully killed nematodes and nematode eggs inside infested roots.**

SWEET POTATO GROWERS have periodically experienced what they call "fumigation failures," even though the soil was fumigated under ideal moisture and temperature conditions with recommended rates of nematocides. Studies in San Bernardino County proved that, instead, these "failures" were caused by contaminated slips brought into the field.

Contamination was coming from two sources; the first being sand—brought in from dry washes and used in the sweet potato slip-producing beds—which growers had formerly thought to be free of nematodes. However, fall rains encouraged the growth of susceptible weeds in this sand, which carried populations of root-knot nematode. This problem was easily overcome by treating the sand with DD or Telone.

The second and major source of contamination was from nematode-infested roots used for slip production. Sweet potato propagation depends on vegetative shoots from the mother roots, which offer an ideal route for the transfer of diseases and nematodes to the succeeding crop. Once seed lots of potatoes become infested, the only known way to overcome this problem is by vine cuttings. Vine cuttings, however, require more labor, considerable land preparation, and extra irrigations. The cuttings are also difficult to establish and usually yield poorly, because they are started late in the season.

Sweet potatoes known to be infested with root-knot nematode were embedded in sand and held at a temperature of 85°F in a greenhouse. Slips from each of three successive pullings were examined for nematode infestations. Some were planted in steamed soil and grown for six weeks—then examined for galls. Only 7% of the 171 slips first pulled were infested. The second pulling of 312 slips showed 90% infestation, and the third pulling of 75 slips, five weeks after the test was started, was 98% infested.

### Dry heat treatment

Three experiments were conducted over several seasons to determine if dry heat could be used as a rapid and safe method for eliminating certain fungi and nematodes. All sweet potato roots used were dug from the field before they became chilled, and then were properly cured and stored. Half of the roots infested with root-knot nematode were placed in boxes in a small, well-insulated heating room, and half were unheated and served as checks.

The temperature was slowly brought up to 110°F for an eight-hour period and held for 24 hours. Thermal probes placed inside some of the sweet potato roots indicated that about 1¼ hours were required to bring the inside temperature of the roots up to the outside room temperature of 110°F. Thermographs were used in the heating room to keep a continuous record of external temperatures during the heat-treating period.

### Tomato roots infested

The infested, heat-treated roots and checks were then sliced, and egg masses were removed. These egg masses were used to inoculate soil in which tomato seedlings were transplanted. Tomatoes were grown for approximately six weeks; roots were then examined for galls. Heat treatment killed all the nematodes, and eggs taken from the untreated roots produced galls on all tomato roots.

The experiment was repeated, except that the temperature was held between 107°F and 110°F, which was one degree