Dry matter production leveled off at the 60 + 60 N rate. The most rapid development of dry matter occurred during the last 31 days of growth (table 2). The maximum uptake of nitrogen, phosphorus, and potassium occurred in the 90 + 90 N plots (table 3). The most rapid absorption of these nutrients was closely associated with rapid dry weight development during the last 30 percent of the crop growth. Similar results were obtained with calcium and magnesium, except at the 60 + 60 N rate. Notes on hollow stem and curd discoloration showed no association with any of the nitrogen treatments.

Conclusions

Split nitrogen applications at the rates of 180 and 240 pounds per acre resulted in maximum plant growth, development, and curd yield of cauliflower. At less than 180 pounds per acre, yields were significantly reduced and curd quality was poorer.

Maximum dry matter production occurred with 120 pounds nitrogen per acre in split applications. As the nitrogen rates increased to 180 pounds per acre, the quantity of nitrogen, phosphate, and potassium absorbed by cauliflower plants also increased. Plant absorption of calcium and magnesium followed a similar pattern up to the rate of 120 pounds of nitrogen per acre. Based on our results, there appears to be little justification for applying large amounts of nitrogen at seeding time, as is commonly done by vegetable growers in the central coast area of California.

Because nitrogen in nitrate form is readily leached out of the soil by water, at least one-half of the total nitrogen should be applied after the first 30 percent of the growing period has passed. Phosphate, potassium, calcium, and magnesium are not readily leached out, so these nutrients can be applied before or at planting time.

Above-ground parts of cauliflower plants at harvest maturity for fresh market absorbed 160 pounds nitrogen, 38 pounds phosphorus, 223 pounds potassium, 80 pounds calcium, and 12 pounds magnesium per acre. Phosphorus is absorbed at only one-fourth the rate of nitrogen, potassium even less. The common practice of using triple-combined fertilizer should be modified so that less phosphorus is used with each crop or the phosphorus is skipped for several plantings.

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Pitch canker threatens California pines

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Although it primarily affects Monterey pines, pitch canker is also a potential threat to other pines in the urban landscape as well as to commercial pine forests and recreation areas.

In the summer of 1986, hundreds of Monterey pines in Santa Cruz County were found with serious branch dieback symptoms that did not fit the pattern of any disorder known in the state. Subsequent investigation confirmed that these symptoms were the result of a disease known as pitch canker, caused by the fungus *Fusarium subglutinans*.

Pitch canker is native to the southeastern United States, from Virginia at the north and westward to Texas. A wide range of pines is affected there, including slash, Virginia, shortleaf, and pitch pines. How or when the fungus reached California is not clear, nor is it certain that the disease occurring here is caused by the same strain of the fungus that affects pines in the Southeast.

The most obvious symptom on Monterey pine is dead branch tips, but entire branches and even tree tops may be dead. A great deal of pitch often oozes from diseased plant parts. The canker is at the junction of dead and living tissue; it is sometimes sunken, yet the bark remains intact. The wood beneath the canker is resin-soaked and honey-colored. Symptoms of new dieback may be seen at any time of year, suggesting that inoculation occurs over a long period. Affected trees become progressively worse in appearance, probably as a result of bark beetles exploiting declining tissue.

Surveys

The California Department of Forestry and Fire Protection has confirmed the principal center of infection to be Santa Cruz County, where several thousand trees are diseased. Smaller diseased areas been identified in the counties of Monterey, Santa Clara, San Mateo, and Alameda.

An obvious symptom of pitch canker on Monterey pine is dead and dying branch tips (left) and resin-soaked, honey-colored wood beneath the canker, as shown in the cut-away version above. Symptoms can be seen at any time of year. The disease has been especially severe in Santa Cruz County.

Besides the most affected tree, Monterey pine, pitch canker has been found on Bishop, Aleppo, and Italian stone pine. Maturing landscape pines, particularly those in dense highway plantings, seem to be most frequently diseased, but pitch canker has been found on smaller isolated trees and, in one instance, in a nursery.

Inoculation trials

Recognizing that many pine species are susceptible to pitch canker in the Southeast, we inoculated seedling, container-grown pines of various species in greenhouse tests. Isolations of the fungus from symptomatic branches collected in the field were made on water-agar medium containing small bits of barley straw or on a medium selective for *Fusarium* species. Branch pieces for isolation were prepared by surface sterilization for one minute in 0.5 percent sodium hypochlorite (household bleach diluted 1:9) followed by removal of the bark. One-quarter-inch chips were cut from the prepared branches, surface-sterilized for one to five minutes in 0.5 percent hypochlorite, then placed on the surface of the agar medium in plastic petri dishes.

We prepared the inoculum by washing fungus conidia (spores) from the surface of 10-day-old potato-dextrose-agar cultures. Its concentration, as determined by hemocytometer, was 330 million conidia per fluid ounce (1.1 x 10^7 per ml).

The pine seedlings to be challenged were growing in nursery containers in greenhouse temperatures ranging from 70° to 80°F. We inoculated 10 trees of each species by placing a small drop (0.02 ml) of inoculum 3/4 inch from the terminal end of succulent green shoots and making a needle puncture through the drop. Control punctures were made in branches and terminals through a drop of water.

All pine inoculations were successful (table 1). Inoculated shoots were girdled in 13 to 21 days. The pitch canker fungus was readily isolated in pure culture from the inoculated, diseased tissues, which became resin-soaked 1/4 to 2 inches from the point of inoculation. None of the control wounds became diseased.

Inoculations failed to infect trees that were not pines: incense cedar, *Libocedrus decurrens;* coast redwood, *Sequoia sempervirens;* and giant sequoia, *Sequoiadendron giganteum.*

TABLE 1. Pines susceptible to the pitch canker fungus, *Fusarium subglutinans* in greenhouse inoculations, 1986-87

Species	Common name
Pinus attenuata	Knobcone pine*
P. canariensis	Canary Island pine
P. coulteri	Coulter pine*
P. eldarica	Eldarica pine
P. halepensis	Aleppo pine
P. jeffreyi	Jeffrey pine*
P. lambertiana	Sugar pine*
P. muricata	Bishop pine*
P. pinea	Italian stone pine
P. ponderosa	Ponderosa pine*
P. radiata	Monterey pine*
P. radiata x *attenuata*	Monterey-knobcone hybrid pine
P. sabiniana	Digger pine*
P. sylvestris	Scotch pine

* Native California trees.

Insect investigations

The pitch canker fungus requires a wound before it can enter to infect a tree part. In the Southeast, injuries made by tree-shaking equipment, cone removal, and storms are implicated in disease incidence in pine seed orchards. Insects, particularly the deodar weevil, *Pissodes nemorensis,* and the subtropical pine tip moth, *Rhyacionia subtropica,* frequently have been found to be contaminated by the fungus. The deodar weevil, after artificial contamination, has been able to inoculate healthy pines in laboratory tests. Although neither of these species occurs in California, related insects and about 50 others feed on Monterey pine in California.

We conducted a laboratory study in which insect larvae, pupae, or adults taken from beneath the bark of diseased branches or twigs, or from cones, of Monterey pine collected in Santa Cruz County were killed and placed on agar medium in petri dishes. Thus far, species of the beetles *Pityophthorus, Conophthorus,* and *Dendroctonus,* and a lepidopterous larva believed to be *Dioryctria* sp., have been demonstrated to be contaminated with the pitch canker fungus. Efforts to inoculate healthy seedling Monterey pines with *Pityophthorus* sp. adults emerging from diseased twigs have not yet succeeded.

Conclusions

Susceptibility of Monterey pine to the pitch canker fungus was demonstrated over 20 years ago in the Southeast. In that instance, stem girdling took eight weeks. In recent California inoculations, stem girdling occurred in three weeks or less, which indicated that the fungus causing disease in California is particularly pathogenic to Monterey pine.

Successful inoculation of all tested pine species, some of them important timber trees, suggests that pitch canker is a potential threat not only to pines in the urban landscape, but also to pine forests used for timber and recreation.

The role of insects in the incidence and spread of the disease in California remains unclear. The fact that insects become contaminated with the fungus does not prove that they serve as vectors of the disease in nature. Their role may be limited to opening wounds in trees, allowing spores of the pitch canker fungus to enter by agents such as wind or rain.

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