FRONTIERS of Plant Science

SPRING 1994
Volume 46 No. 2

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THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION,

founded in 1875, is the first experiment station in America. It is chartered by the General Assembly as an independent State agency governed by a Board of Control. Station scientists make inquiries and experiments regarding plants and their pests, insects, soil and water quality, food safety, and perform analyses for State agencies. Factual information relating to the environment and agriculture is provided freely and objectively to all. The laboratories of the Station are in New Haven and Windsor; its Lockwood Farm is in Hamden. Copies of this and other publications are available upon request to Publications; Box 1106; New Haven, Connecticut 06504

ISSN 0016-2167

Dogwood anthracnose severity is influenced by timing of spring rains

By Victoria L. Smith

Dogwood anthracnose, caused by the fungus *Discula destructiva*, was described in the late 1970s in New England and in the Pacific Northwest. The disease is now present throughout most of the natural range of the flowering dogwood, *Cornus florida*. Another popular dogwood, the kousa dogwood, *Cornus kousa*, can also be infected, but the effects are not as severe. Dogwood anthracnose also has been reported on red-twig dogwood, *C. sericea*, Pacific dogwood, *C. nuttallii*, and bunchberry, *C. canadensis*.

The most obvious symptom of infection by *D. destructiva* is a leaf blight, resulting in purple-bordered tan lesions. Infection is initiated by spores of the fungus that have overwintered in infected twigs. In late spring, spores are spread from the twigs to young susceptible leaves by splashing rain. If there is sufficient moisture, the resulting lesions will be large. Lesion development, however, will be constrained by hot, dry conditions.

In addition to causing leaf blight, the fungus also can infect the flower bracts, causing unsightly pink to purple splotches. Bract infection can occur on both *C. florida* and *C. kousa*. Since bracts drop off trees rapidly following infection, bract blight is not as serious as leaf blight.

Leaf infections can progress down the petiole and into the twigs, causing a twig blight. Infected twigs turn purple and usually die, with fruiting bodies of the fungus forming on blighted twigs. The fungus produces toxins that are involved in the formation of cankers on the main stem of the tree at the base of blighted twigs. The tree can be killed when one or more cankers girdle the main stem, although I have not seen this in Connecticut.

Figure 1. Victoria L. Smith and a dogwood with its leaves beginning to expand.

In past years, it was difficult to find a tree in Connecticut that was not infected with anthracnose. Many were severely defoliated, and cankers were common on the branches and trunk. In some areas, death of trees within one summer was not unusual. Previous investigators assumed that summer droughts and colder than usual winters were weakening the trees and exacerbating the effects of the disease, but the exact cause of tree mortality was not clearly understood.

The leaves of kousa dogwood are highly resistant to anthracnose, and hybrids of *C. florida* and *C. kousa* have recently become available. The hybrids have characteristics of both parent trees; some have floral characteristics similar to *C. florida*, while others have a shape and branch structure similar to *C. kousa*. The trees are more vigorous than either parent, growing rapidly in the spring and early summer; however, they are also susceptible to anthracnose.

I have been collecting data on severity of naturally-occurring epidemics of dogwood anthracnose in Connecticut during the past 4 years. My experimental plots are in: Hamden, Westchester, North Branford, and Deep River. At weekly intervals at these four sites, I collected fifty leaves; each lesion on each leaf was counted and its length and width measured. Number of leaves with lesions was used as a measure of disease incidence. Total surface area of each leaf was then measured with a leaf area meter. The percentage of the leaf area diseased was then calculated and used as a measure of disease severity.

Leaves emerged and were 1 cm long between May 1 and May 8 over all years sampled at all sites. Disease first appeared about 4 weeks after that, on or about May 30. On some sites, first lesions appeared as late as June 15. Apparently, the "window" of first lesion occurrence is about 4 to 6 weeks after leaf emergence, usually from mid-May to the end of May. After the "window" of lesion occurrence closes, about 7 weeks after leaf emergence, there are no new cycles of infection. Older leaves seem to be not susceptible to infection by *D. destructiva*.

Occurrence of the first and only flush of lesions corresponds to rainfall events during leaf expansion. When there is a rain during the period of leaf expansion, there is a good chance of leaf infection. Correspondingly, if there are more rain events, the probability of leaf infection increases. When I examined the number of rain events for the month of May from 1990 to 1993, I found little relation to the amount of disease. However, when I looked at rain events when the leaves were fully expanded but still only 2 to 3 weeks old, I found a strong relationship between rain events during the last 2 weeks of May and the total amount of disease in any given season. If more than half of the rain events in May occurred in the last 2 weeks, disease was greater than if there were few rain events. Interestingly, the amount of rain did not seem to matter. Timing seems to be more important. If there were few or no rain events in the "window", lesion development was constrained, as in 1991. These findings are consistent over four seasons, although the seasons have been very different climatically. For simplicity, I have presented data from the Lockwood Farm site in Hamden.

Since infection apparently occurs only during a short period of time in the spring, that may be when we need to give the trees a little extra care, which will enhance the tree's ability to withstand the disease. Dogwoods are shallow rooted, and greatly benefit from 1-2 inches of water per week, especially during hot spring and summer months. How supplemental water is applied is important; wetting the leaves during leaf expansion should be avoided to prevent transmission of the fungus during the susceptible interval. Mulch, such as wood chips, will aid in conserving soil water, and will protect the base of the tree from cuts inflicted by lawn mowers or string trimmers. Pruning of infected twigs and removal of infected leaves will improve the appearance of the tree and will remove some of the anthracnose fungus from around the tree. Application of fertilizer in the early spring also will boost tree vigor

We have come a long way in understanding how the fungus *Discula destructiva* causes disease in dogwoods. We know where it overwinters, when it infects, and some measures that can be taken to reduce infection. With a little care and effort, dogwoods will remain a vital and beautiful part of our Connecticut landscape and forests.

Composted municipal solid waste beneficial as a soil amendment

By Abigail A. Maynard and Gregory J. Bugbee

Today, as the shortage of disposal sites is reaching crisis proportions, composting the organic fraction of solid waste is being explored as a means of diverting large amounts of materials from landfills and incinerators. Composting, which produces a useful soil amendment, can be considered a supplement to traditional forms of recycling.

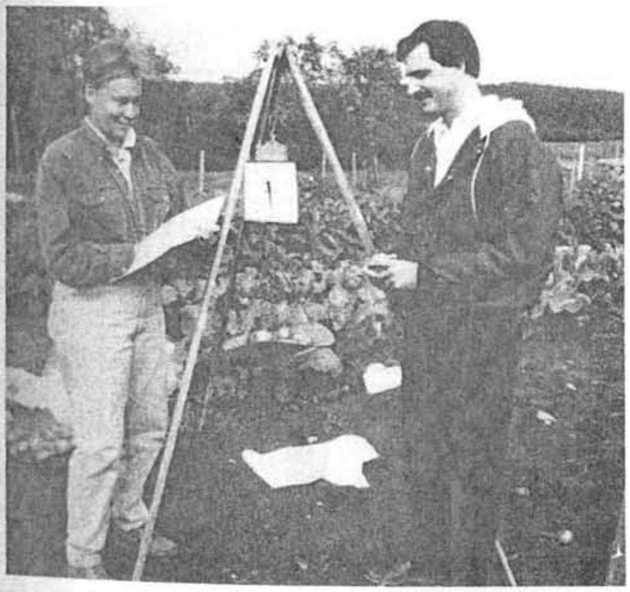

Figure 1. Abigail Maynard and Gregory Bugbee weigh tomatoes harvested at Lockwood Farm.

Table 1. Average number of tomatoes/plant, weight/tomato (oz), and yield (lbs/plant) in plots amended with 25 or 50 T/A compost compared to unamended control.

Treatment	no./plant	oz/tomato	lbs/plant
Control	17.6	7.06	7.8
25 T/A	20.8	7.34	9.5
50 T/A	22.0	7.86	10.8

In March 1992, The National Audubon Society and Procter & Gamble, in cooperation with The Connecticut Agricultural Experiment Station, sponsored a demonstration project to determine the viability of composting as a way to manage solid waste and to learn how much compostable material could be captured from homes and businesses. About 500 households in Fairfield and Greenwich, as well as several McDonald's restaurants in Fairfield, participated in a 1 month trial. The volunteer households sorted their compostable materials—food scraps, soiled paper, kitty litter, milk cartons, pizza boxes, diapers, napkins, tissues, and dry paper packages—into a separate paper compost bag which was lined with a cellophane-like moisture barrier. Materials such as plastic, metal cans, newspaper, and glass that are recycled by other means were not placed in the bag.

The bags were collected weekly, weighed, and taken to an existing compost facility in Fairfield. Analysis of the weights of the wastes collected from the homes showed that the participants already recycled 40% of their household trash. The compost bag captured another 30%, leaving only 30% for disposal.

At the composting facility, the bags and their contents were shredded and yard waste, such as leaves and woodchips, was added to achieve a typical blend of residential compostable waste. The material was then composted for 30 days in an agitated in-vessel system designed by International Process Systems. The finished compost was then passed through a 3/8th inch screen before use.

We conducted growth studies with the finished municipal solid waste (MSW) compost, utilizing it as a soil amendment in field-grown tomatoes and as a replacement for peat, perlite, and sand in a standard potting medium.

Tomatoes were grown at Lockwood Farm in Hamden on a loamy upland soil with a moderate moisture holding capacity. Each plot was 10X10 ft. surrounded by 3-foot aisles and replicated four times. The compost was applied on June 19 at the rates of 25 or 50 tons/acre (T/A) (dry weight basis), equivalent to a layer of about 1/2 inch and 1 inch of compost, respectively. The compost was incorporated into the soil by rototilling. Control plots received no compost. All plots were fertilized once before planting with 10-10-10 fertilizer at a rate of 1300 lbs/A.

The tomatoes (cv. Celebrity) were seeded in a greenhouse on April 27. They were transplanted in the field on June 22 in rows 4 feet apart with a spacing of 2 feet within the rows. There were 10 plants per plot. Vegetative suckers were removed up to the first flower cluster on July 20 and the plants staked. Tomatoes were harvested weekly from August 26 to October 8 and the marketable yield from each plot was recorded. Soil samples were obtained from each plot in October at the end of the harvest.

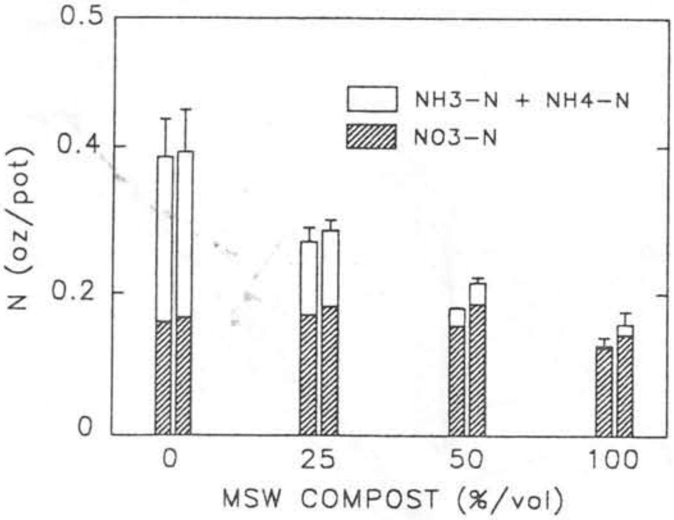

Figure 2. Nitrogen leaching from media as NO_3-N and NH_4-N + NH_3-N. Left bar of each pair indicates plants grown without liquid fertilizer. Right bar corresponds to plants grown with liquid fertilizer. Error bars denote one standard error of the mean for total N.

Average yield (lbs/plant) from plots amended with 50 T/A compost was 38% greater than yields from unamended control plots (Table 1). This significantly higher yield was due to increases in the number of tomatoes per plant and average weight of each tomato. Yields from plots amended with 25 T/A compost increased 23% compared to the control but the difference was not statistically significant. Timing of the harvest was not affected by the treatments.

The increase in yield on the compost-amended plots can be attributed to changes in various soil characteristics. The pH of the soil increased to an average of 6.2 on the plots amended with 50 T/A compost compared with 5.4 on unamended controls. Although all plots received the recommended amount of fertilizer for tomato culture, pH affects the availability of the nutrients to the plants. A pH range of 6-7 is considered optimum for both microbial activity and nutrient availability. The addition of the compost had a liming effect and raised the pH into the optimum range.

The addition of 50 T/A compost also increased the organic matter from 5.0% to 6.9%, an increase of 38%. The increase in organic matter in the first year was similar to that found with comparable application rates of chicken manure compost and spent mushroom compost in another study. It is known that organic matter increases the supply of soil nutrients, improves soil structure, moisture retention, aeration, and friability. In addition, nitrogen, phosphorus, and micronutrients held in organic forms are less prone to leaching. In 1992, improvements in moisture retention were not likely to be significant because of an abundance of rainfall.

Our colleague David Stilwell analyzed tomato fruit to determine metals taken from the soil. Of 17 elements analyzed, only sodium and phosphorus had significantly higher levels in compost-amended plants, but the levels were below the national average in tomatoes. Cadmium and beryllium levels were significantly lower in plants from the compost-amended plots compared to the unamended controls.

Municipal solid waste compost could also be an economical replacement for costly potting media components used by Connecticut's nursery industry. To test this possibility, black-eyed Susans (*Rudbeckia* cv. 'Goldilocks') were grown in 2-quart pots filled with a conventional medium containing peat, perlite, and sand (50:30:20 by vol.) and experimental media containing 10, 25, 37, 50, 80, and 100 (percent by vol.) MSW compost. Compost replaced part of the peat in the 10, 25, and 37% media, all of the peat in the 50% medium, and the peat and perlite in the 80% medium. Leachate from media containing 0, 25, 50, and 100% compost was tested for nitrate (NO_3^-), ammonia (NH_3), and ammonium (NH_4^+). These forms of nitrogen could be potential sources of nitrates in surface and ground waters in the vicinity of greenhouses and nurseries. The effects of two mid-season applications of liquid fertilizer on plant growth and nitrogen leaching were also examined.

High quality black-eyed Susans were grown in media containing all proportions of MSW compost compared to the conventional medium. Greater growth was observed when plants were liquid fertilized, however the increases were not statistically significant. The potential for leachate to be a source of nitrate was slightly reduced as the amount of compost increased (Figure 2). Liquid fertilizer did not significantly change the amount of nitrogen found in leachate, probably because it was applied to rapidly growing plants that quickly utilized the water-soluble nitrogen. Nitrogen leaching was not related to the amount of leachate obtained from each treatment.

A reduction in nitrogen leached by media containing MSW compost could be helpful in formulating media with a reduced potential to add nitrates to surface and ground water. Organic materials with high C/N ratios are known to bind nitrogen; however, the MSW compost had a moderate C/N ratio of 29. Composts tested in other experiments had similar C/N ratios but did not reduce the nitrogen in leachate. The uniqueness of MSW compost in relation to reduced nitrate in leachate needs further investigations.

Our experiments show that MSW compost can improve the yield and quality of field and container grown crops, while using 30% of household waste as a raw material.

Several environmental modifications reduce risk of tick bite

By Kirby C. Stafford III

Several tactics, including the application of insecticides, manipulation of hosts, modification of the environment, and host-targeted insecticides, have been tried as potential controls of the black-legged tick, *Ixodes scapularis*, (formerly the deer tick, *Ixodes dammini*), which transmits, *Borrelia burgdorferi*, the spirochete (bacterium) that causes Lyme disease.

Area applications of insecticides are effective in eliminating or substantially reducing *I. scapularis* from relatively small areas such as individual yards. In one of the first studies of the use of an insecticide (i.e. carbaryl) against nymphs of *I. scapularis* in yards and adjacent woodlands, I found that one spray application in late May to early June controlled this stage for most of the summer. Subsequent studies have shown that one application of other insecticides, such as chlorpyrifos and cyfluthrin, are even more effective.

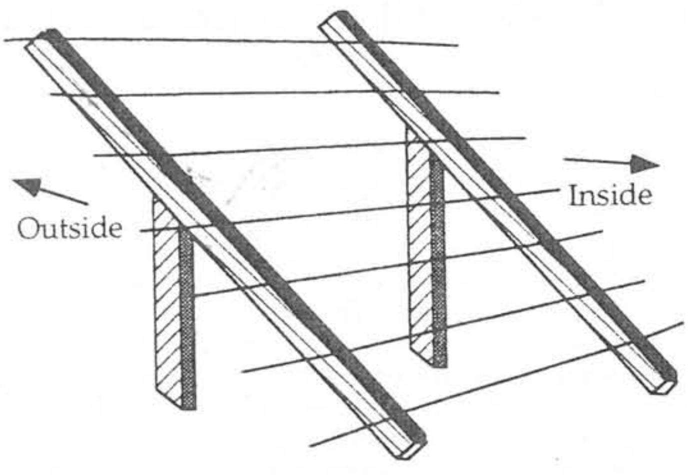

Figure 1. Diagram of one section of a slanted, seven-wire, high-tensile electric deer fence.

White-tailed deer appear crucial to the reproduction of *I. scapularis*, and there is a close association with the abundance of deer and the abundance of this tick. Therefore, the exclusion of deer may reduce the risk of contact with spirochete-infected ticks. To assess the effect of exclusion on populations of *I. scapularis*, I monitored host-seeking ticks inside and outside a wooded, residential deer exclosure (ca. 8 acres) in Lyme in 1991 and 1992. Another deer exclosure in Lyme (ca. 18 acres) was added in 1992.

A seven-wire, slanted, high tensile electric deer fence was used at both sites (Figure 1). The fence slants away from the area to be protected at a 45 degree angle with the top wire approximately 4 feet above the ground. As deer attempt to crawl under the fence, they encounter the lower wires and are unable to jump over the strands.

The abundance of host-seeking *I. scapularis* was determined by "dragging" the vegetation with a square yard of white flannel cloth fastened along one side to a wooden dowel. Ticks clinging to the material were counted and tested for the presence of *B. burgdorferi*. Drag sample plots were established in the woods inside the fences, outside the fences, and at other residences in the region that served as secondary control sites. Tick infestations on white-footed mice were monitored by live-trapping. The mice were examined for ticks and released.

I found that larvae of *I. scapularis* were 81.5% (1991) and 97.8% (1992) less abundant within the exclosure than immediately outside. Nymphs of *I. scapularis* were 47.4% (1991) and 55.8% (1992) less abundant within the deer fence. The impact on adult ticks was mixed. No difference in tick abundance was seen at the 8-acre site. However, larvae, nymphs, and adults were 100, 83.8, and 74.1% less abundant, respectively, in plots at the 18-acre exclosure, 230 feet from the deer fence and isolated from woodlands outside the fence by lawns, driveways, and buildings.

The recovery of larvae and nymphs of *I. scapularis* from mice captured within the deer exclosures indicates that infestations of nymphs and adults are probably, at least in part, a result of the movement of these rodents. Based upon the number of nymphs infected with *B. burgdorferi*, there were 73 and 82% fewer infected nymphs within the deer exclosures in 1992 outside the fence and at the secondary control sites, respectively.

Several lines of evidence suggest that another approach to tick control could be vegetative modifications to the environment. Increases in solar exposure and reductions in the relative humidity (RH) may help reduce tick numbers. I found that half of the nymphs of *I. scapularis* held at 75% RH and 80F will die in 10.7 days. At 65% RH, all the nymphs died within 8 days. All nymphs survived for at least 149 days at 100% RH. The distribution of *I. scapularis* within residential landscapes also suggests that altering the vegetation could reduce tick numbers on lawns. Characteristics of each lawn and the type of edge bordering the lawn appear to be important determinants for the presence of *I. scapularis*. Dr. Louis Magnarelli and I studied the spatial distribution of this tick at 10 residential sites in woodlands during 1989-1991 to help pinpoint high risk areas and the best places to target insecticide applications. The majority of host-seeking *I. scapularis* larvae (84.2% of 7,385) and nymphs (73.5% of 2,202) were collected within woodland plots, while a large proportion of the 412 adults collected were recovered from lawns (36.4%) and transitional areas between the lawns and woodlands (20.9%). The majority (71.1%) of all stages of *I. scapularis* on the lawn were recovered within 1 yard of the lawn edge, particularly along the woods and stone walls.

Ticks were generally most abundant on lawns when they also were abundant in adjacent woodlands. However, there were several exceptions where virtually no ticks were recovered from the lawn although tick densities were high in the adjacent woods. These were lawns with little or no shade. An increase in the size of the lawn may also reduce the number of ticks by increasing the distance of the residence from the woodland and/or stone wall edges.

Smaller lawns appear to have the highest risk of tick contact. A larger proportion of the lawn would be within 0 to 3 yards of the woods, stone walls, or both, where the majority of the ticks would be found. These areas would be more likely to possess a substantial amount of shade and ornamental vegetation. Casual observation of the landscape of many homes suggests that the side and back lawns, where residents spend most of their time, tend to be smaller with closer proximity to the forests than the front lawns.

The application of insecticides remains the most effective method to control *I. scapularis* in individual yards. Only one application appears necessary to control the nymphs during the summer season. The exclusion of deer in conjunction with other tick control strategies in large areas could substantially reduce populations of *I. scapularis*. Mowing the vegetation, removing leaf litter, pruning trees, clearing brush, and cutting back the immediate overstory should reduce the suitability of the environment for ticks.

The risk of tick bite varies in highly endemic communities, and more detailed knowledge about the natural cycle of the tick, the spirochetes, and their hosts with respect to the residential landscape may lead to other approaches to reduce tick abundance and the risk of acquiring Lyme disease.

Using transgenic plants for biochemical and genetic improvement of crops

By Israel Zelitch

A recent visitor from Belarus winced when I talked excitedly about eating corn this summer. Elsewhere, corn is just starchy and tough animal feed. Yet in Connecticut we know that if sweet corn is fresh we are likely to have flavorful kernels to eat. Why is there such a difference in food preference? In this country, using methods pioneered at The Connecticut Agricultural Experiment Station, corn breeders have produced varieties with kernels having a greater sugar content and slower conversion of sugar to starch.

Taste is not the only trait that can be bred into corn; but varieties can be adapted to different environments and be given resistance to diseases and pests. To obtain them, geneticists and plant breeders select recognizable traits. Then, by placing pollen from the tassels of one corn plant onto the silks of another they produce new offspring with characteristics different from the parents. These plants are further tested and crossings or self-pollinations are carried out until the desired characteristic is fixed genetically.

A simple but elegant example of how corn breeders operate comes from the work of Donald F. Jones, a geneticist at The Experiment Station from 1915-1960. Since winds often ruined corn plants, Jones looked for "strong stalk" genes about 50 years ago. Toward the end of a season Jones and his associates went through their fields of different kinds of corn plants and kicked the stalks. One plant that would not fall over when kicked became the forerunner of a corn inbred line known as C-103. The "C" is for Connecticut. Its genes are still used today in producing

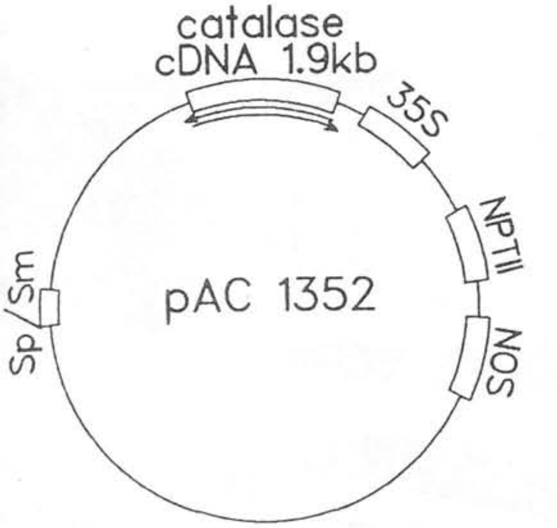

Figure 1. Diagramatic representation of a plasmid DNA, pAC 1352, containing inserted leaf catalase DNA. The DNA is read in a unidirectional, counterclockwise, orientation. NOS is a promoter that drives expression of NPTII which confers resistance to the antibiotic kanamycin to plants that incorporate the plasmid. CAMV 35S is a constitutive promoter (on at all times throughout the plant) that turns on the production of catalase in the sense or antisense sequence (as shown by arrows in both directions). The plasmid also confers resistance to the antibiotics streptomycin (Sm) and spectinomycin (Sp). The kanamycin-resistance trait is used as part of the evidence that transgenic plants have been produced since tobacco lacking the plasmid would be killed by this antibiotic.

most of the hybrid corn seed planted around the world.

It takes many years of skillful selection and breeding to create an improved crop or horticultural variety, and often requires the cooperation of plant pathologists (disease), entomologists (insects), and increasingly biochemists and molecular biologists. An examination of seed catalogs in the spring will show, for example, that some tomato varieties have genetic resistance to diseases such as verticillium and fusarium wilt, nematodes, viruses, and fungal blights.

In all the genetic changes described, plant breeders have modified the plant's DNA, deoxyribonucleic acid, since all genetic information is encoded in these large molecules. DNA consists of a long string or sequence of interconnected bases, sugars, and phosphate groups. There are four bases in DNA abbreviated as A (adenine), G (guanine), C (cytosine), and T (thymine). Different plant varieties can be distinguished by subtle differences in the base sequences of their DNA which acts like a "fingerprint."

Three consecutive bases are required to code for the later synthesis of a specific amino acid. For example, the sequence "ATG" codes for the amino acid methionine. A fixed sequence of amino acids coded by the gene (DNA) acts as a mold for producing complicated proteins, including enzymes which are proteins catalyzing biochemical reactions in living cells. An enzyme that has 500 amino acids would be encoded by a DNA molecule that would have at least 1,500 bases (500 X 3).

One of the exciting recent opportunities in plant genetics has come from the development of methods for moving genes in the form of isolated DNA from one plant to another. Such plants are known as transgenic plants, and scientists in the Department of Biochemistry and Genetics at the Experiment Station are using these plants to do the laboratory equivalent of "kicking stalks." Except, instead of using boots, we use sophisticated equipment and chemicals to search for star protein-makers and efficient energy-converters.

Our emphasis has been to produce transgenic plants with altered leaf biochemistry to enhance photosynthesis, the driving force of plant productivity that captures solar energy, and to improve the rate of leaf development. The

Testing for genes and what they do

To make transgenic plants, a "library" containing the DNAs encoding thousands of genes of a tobacco leaf was first probed using a catalase DNA from cottonseed isolated by scientists in Arizona. The cottonseed catalase DNA can recognize and bind to tobacco catalase DNA. In this way a full-length DNA molecule encoding for tobacco leaf catalase was isolated and cloned. In collaboration with scientists at Yale we determined its base sequence (about 1,900 bases) and predicted its amino acid composition. A colleague, Louise Brisson, using genetic engineering techniques, incorporated the catalase DNA into circles of a DNA carrier vector, called a plasmid. The engineered vector (Figure 1) was then transformed into bacteria for multiplication. Since the genetic code is read in one direction, the DNA could be inserted in "sense" (the correct direction) and "anti-sense" (the incorrect direction) configuration (arrows in Figure 1). The plasmid contains a promoter region that signals the cell to overproduce the stretch of DNA on the plasmid that follows, and in the sense mode the catalase synthesis should increase while in the antisense configuration enzyme expression should be blocked. The plasmid was finally incorporated into the genes of tobacco leaf tissue using *Agrobacterium*, a bacterial infectious agent, which can transfer its DNA into the DNA of the leaf.

Figure 2. Israel Zelitch views a transgenic plant.

tobacco plant is often used as a model, but the principles learned can be applied to improving food crops as well.

One area of research involves isolating the gene that encodes the enzyme catalase, an enzyme that breaks down toxic hydrogen peroxide to form harmless oxygen and water (H_2O_2 ---> $\frac{1}{2}O_2$ + H_2O), and the creation of transgenic plants which overexpress or underexpress this enzyme. These experiments resulted from a discovery made from more conventional plant selection and breeding.

Although oxygen is necessary for growth, photosynthesis in most agricultural crops is inhibited 33 to 50% by the level of oxygen in air (21%) and is blocked more severely at higher oxygen levels. This inhibition results from the oxygen-dependent process of photorespiration that produces carbon dioxide in light. I had an idea that plants which did well at higher oxygen levels could be super-achievers in normal air.

To obtain plants with oxygen-resistant photosynthesis I screened large numbers of tobacco plantlets grown in twice-normal levels of oxygen (42%) and selected several that grew well under these unfavorable conditions. One of these mutant plants and its descendents showed about 15% greater photosynthesis than normal plants in normal (21%) oxygen and 35% higher photosynthesis in 42% oxygen. This was clearly a high achiever, photosynthetically, so we investigated why. We found more catalase protein in the leaves and about 40% greater catalase activity. We seem to have discovered a plant "gifted" with catalase and efficient at removing the poisonous hydrogen peroxide.

Both kinds of transgenic plants have been created, having elevated and reduced levels of catalase (Box/Figure 1), and these are being self-pollinated to obtain seed for the next generation so we can test the role of catalase on photosynthetic efficiency.

Another modern stalk-kicking investigation we have worked on is based on the dilemma that although the more light, the better the photosynthesis, the efficiency (ratio of carbon dioxide uptake per quantum of light) decreases in very bright light. Yellow pigments in chloroplasts called xanthophylls are believed to work against efficiency at high light levels.

Richard Peterson has been studying environmental effects on photosynthetic efficiency of leaves, and Evelyn Havir has been purifying one of the enzymes of the xanthophyll cycle from spinach leaves. Once pure protein is obtained, the amino acid sequence of a segment can be determined, and the base composition of a DNA sequence coding such a segment can be synthesized. Antisense transgenic plants can then be produced to change the role of the xanthophyll cycle in photosynthetic efficiency in an unequivocal manner.

Leaves are the main organs of light absorption in photosynthesis, and Neil McHale and Francine Carland have been investigating the genetic, cellular, and molecular biological basis of leaf initiation and expansion. A tobacco mutant has been obtained in which leaf midribs are normal but leaf blades fail to form. Another mutant has been obtained which produces leaves in odd places such as growing out from a midrib and has similarities to a leaf mutant previously found in California in corn leaves. Transgenic tobacco plants have been obtained using the corn DNA and similarities and differences between these mutants are being explored.

These studies represent pioneering efforts in the genetic regulation of leaf initiation and expansion and should lead to opportunities to control these processes to optimize light utilization in photosynthesis in a manner that is not now possible by classical plant breeding. When such genetic engineering techniques are perfected, they can be used to improve the yields of a wide variety of crop plants.

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