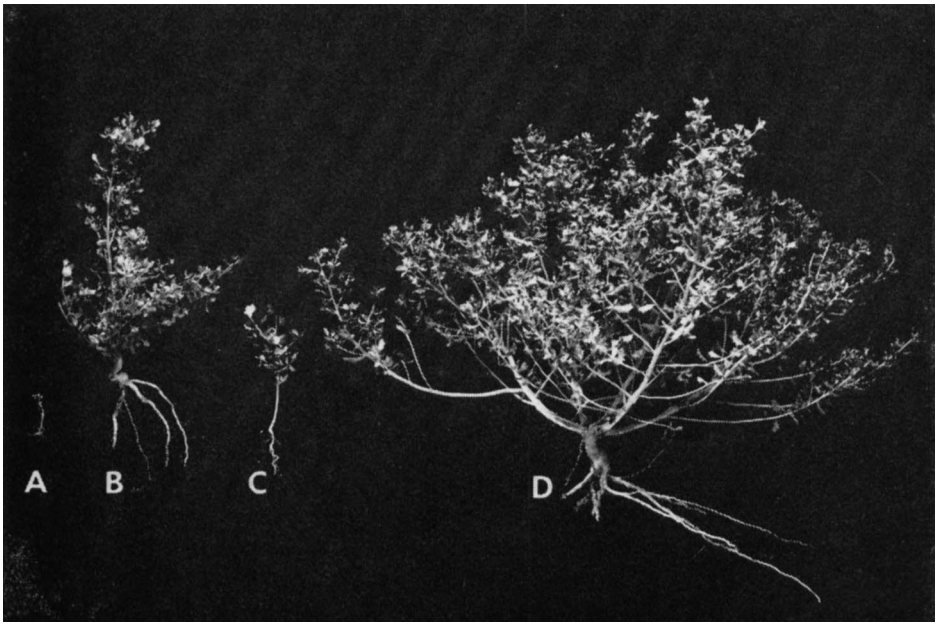
C. E. YARWOOD

Tillage practices have contributed greatly to increasing crop production. However, speculation and controversy have surrounded such practices as to the question of whether tillage increases or decreases the incidence of disease in the growing crop. This study substantiates recent investigations indicating that tillage does, in fact, generally increase the incidence of plant diseases.



Representative Baccharis plants from tillage trials (all were about size of plant A at transplanting): (A) planted February 13, 1968 in native grass sod; (B) planted February 13, 1968 in clean cultivated soil and maintained free of weeds by tillage; (C) planted October 4, 1967 in clean cultivated soil but not further treated; and (D) planted October 4, 1967 in clean cultivated soil and maintained free of weeds by tillage—all photographed September 3, 1968.

STUDIES OF the relation of tillage to disease have been difficult in the past because most crops have been practically nonproductive without tillage. If corn, potatoes, beans, cotton, grapes, etc. were planted in otherwise undisturbed soil in the regions where they are commercially produced, these crops would be smothered out, or otherwise repressed, by the native vegetation, and the incidence of conventional parasitic diseases on the planted crop could not be readily observed. Usually this would still be true even if the land were thoroughly cultivated before planting the crop, and not cultivated afterwards, because weeds would usually smother the crop. The availability of chemical weed killers and plastic covers to suppress weed growth has made possible the successful production of many crops previously successful only with extensive tillage.

It has been estimated that food production has been increased 6,000-fold per unit area of land by the transition of civilization from food-gathering to cultivation agriculture. This transition was largely completed several thousand years ago. If a food plant subjected to tillage yielded less than the same plant in nature because tillage favored disease, or for any other reason, tillage of such a plant would have been discontinued. Only plants responding to tillage with great increases in yield, and without a disastrous increase in disease, were maintained in the evolving agriculture. Therefore, spectacular increases in disease due to tillage are not likely to be found now among conventionally cultivated crops. To detect possible major increases in disease as a result of tillage, it is necessary to study the effect of tillage on conventionally non-tilled plants.

Coyote brush

Baccharis pilularis var. *consanguinea* (Compositae, coyote brush, chaparral broom) has been the principal species observed in this study. *Baccharis* is a native, evergreen, broadleafed, perennial shrub which dominates thousands of acres of the uncultivated coastal hills of California and occurs to a lesser extent in the Sierra foothills. It is not normally cultivated, is generally considered a nuisance, but is eaten by deer and cattle to a limited extent. Its suitability for this study was indicated by the abundance of powdery mildew on wild plants immediately adjacent to a recently cultivated area in Pt. Reyes National Seashore on Santa Lucia soil in 1963 and 1964, and the virtual absence of this powdery mildew elsewhere. Experimental plantings were therefore made at Pt. Reyes to test the hypothesis that tillage favored this and other diseases. This area had the advantage that native *Baccharis* was abundant adjacent to the experimental plantings and could serve as a large reservoir of inoculum for endemic diseases and other pests of *Baccharis*. Seedlings from nature were transplanted, mostly during November-February to grass sod and to cultivated soil at various distances from grass sod. Also, plants were set 1 ft apart in rows 3 ft apart in thoroughly cultivated weed-free soil. Parts of these rows were hoed to destroy weeds while other parts were not hoed and the weeds grew luxuriantly. The plants were usually watered once at transplanting but no further water and no fertilizer was added. The natural rainfall of the area is about 30 inches per year, mostly from December through March, with practically no rain during the summer months.

Other plants

Other plants planted with the same spacing in the same area, with and without tillage, were potato, broad bean, barley, sunflower, artichoke, buckeye, tan oak, live oak, self heal, grass poly, wart cress, tarweed (two species), star thistle, sow thistle, bull thistle, hedge nettle, California poppy, sour grass, wild buckwheat, yarrow, cow parsnip, plantain, wild iris, cotton batting plant, skunkweed, Australian fireweed, common man root, willow, yarrow, scarlet pimpernel, and *Datura* sp. Of these, only the first five are standard cultivated plants, the others are mostly native species and weeds.

On most of these 34 species, no parasitic diseases were recognized during the five years they were studied in this area, nor were the relatively rare parasites identified. On one species of tarweed *(Madia sativa* var *maritima)*, rust *(Coleosporium madiae)* and powdery mildew *(Sphaerotheca humuli)* were

TILLAGE *increases plant diseases*

about equally abundant on tilled and non-tilled plants. On wild iris *(Iris longipetala)*, rust *(Puccinia iridis)* was about equally abundant on tilled and non-tilled plants. On yarrow *(Achillea millefolium)* and hedge nettle *(Stachys rigida)* the powdery mildew *(Erysiphe cichoraceae-rum)* was about equally abundant on tilled and non-tilled plants.

Host species

On eight host species shown in the table, 15 species of fungi or insects were more abundant on tilled than on non-tilled plants. Of these, the most extensive observations and the greatest differences due to tillage were with *Baccharis*, where five insect and fungus pests were more abundant on tilled than on non-tilled plants. With *Baccharis* especially, and with the other species to a lesser extent, the greater incidence of disease was clearly associated with the greater succulence and growth rate of the tilled plants. Of plants transplanted into clean cultivated ground on November 27, 1965, and weighed July 9, 1966, the average green weights per plant for subsequent treatments were as follows: not cultivated, 0.43 g; cultivated on one side only, 35 g; and cultivated for a distance of 3 feet on all sides, 266 g. The most objective index of vigor other than green weight was maximum size of leaves. The maximum width of leaves of non-tilled plants was 22 mm, whereas the maximum width of leaves of tilled plants was 38 mm. The most luxuriant development of powdery mildew was on the large lower leaves of the tilled plants. The predominance of mildew on the lower leaves is believed to have also been favored by shade.

Indirect effects

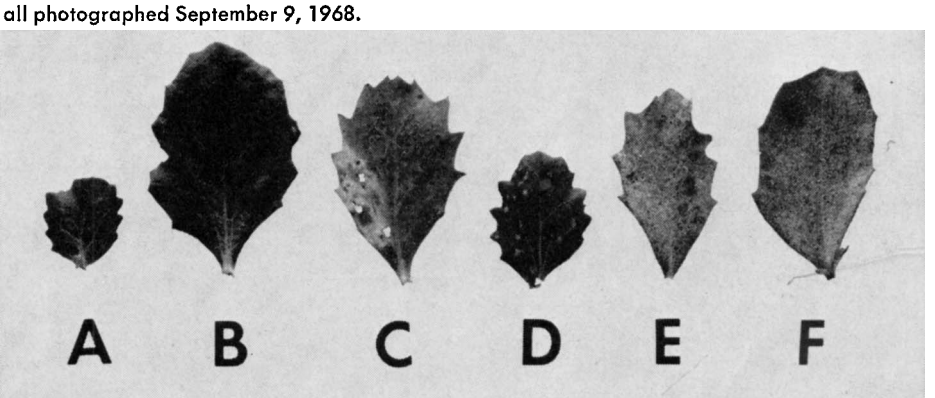
In the above examples with diseases and pests believed to be not soil-borne, the increases in disease associated with tillage probably occurred indirectly through some effect of tillage on the host plant, since tillage can hardly have any direct effect on the pathogen. The greatest effects of tillage on disease are expected with soil-borne diseases, where tillage can exert its effect on the pathogen directly as well as through its effect on the host. But the common increase in soil-borne diseases, resulting from planting a cultivated crop several years in succession in the same soil, is not necessarily because tillage increases the pathogen or the disease. It is just as likely that the increase in disease resulted from the buildup of the pathogen in the soil or on the host, independent of cultivation. This mechanism was not believed to operate in the examples observed in this study.

The only disease observed in this study which was apparently reduced by tillage was chocolate spot of broad beans caused by *Botrytis cinerea*. Broad beans cultivated on only one side had more chocolate spot in 1966 than non-cultivated broad beans or those cultivated on two sides. The increase in disease in this case is presumed to be due to the heavy growth of grass which created a moist microclimate favorable for *Botrytis* infection. This exception does not invalidate the general conclusion that tillage usually increases disease.

Covering

To control weeds and eliminate competition without tillage, black plastic sheeting was used to cover the vegetation and

Representative Baccharis leaves from tillage trials: (A) normal mildew and rust-free leaf from non-cultivated plant; (B) leaf from "water sprout" of cultivated plant which was cut back July 4, 1968 and which "escaped" mildew and rust infection, showing the effect of tillage on leaf size in absence of disease; (C) telial pustules of rust, Puccinia evadens, on lower surface of old leaf of cultivated plant; (D) pycnia of rust on upper surface of young leaf of cultivated plant; and (E), (F) powdery mildew Erysiphe cichoracearum, on old lower leaves of cultivated plants—all photographed September 9, 1968.



soil at various distances beyond small volunteer, non-tilled *Baccharis* plants in 1967 and 1968. This treatment increased the growth, mildew, and rust, almost—but not quite—as much as tillage.

To reduce growth in the absence of weed competition, as well as to produce a gradient of light intensity, plants in tilled and untilled areas were partially covered with white wooden boxes. Mildew on the shaded portions of these tilled plants was more severe than on the unshaded portions of the same plants. In the deep shade, mildew extended to the leaves at the tops of the shoots and apparently killed many leaves, whereas in the full light, mildew usually did not extend to the tip leaves, and even the heavily mildewed lower leaves were usually not killed. To what extent the death of the leaves in shade was due to mildew and to what extent it was due to the shade *per se* could not be decided since the test showed no mildew-free leaves in the shade.

Dosages of ammonium nitrate, sodium phosphate, and potassium chloride of up to 5 grams per plant, were applied to small non-tilled *Baccharis* plants in sod to test the effect of nitrogen, phosphorus and potash on disease development. There was no clear response to these nutrients, and no mildew was observed on any of the fertilized plants.

To produce succulent growth without tillage, large (about 30 lbs) uncultivated plants that had suppressed the adjacent vegetation were cut off near the ground level. Such plants produced a succulent sucker growth with large leaves which became heavily mildewed.

To observe the effect of controlled competition, *Baccharis* plants were set at distances of from 5 to 30 inches between plants in both directions, and kept free of weeds. Growth and mildew increased with space per plant, but even plants with 5-inch spacing had more mildew than wild plants in competition with grass at any spacing observed. After one season, half the plants in the spaced plot were cut off about 1 inch above the soil level. In the next season, the vigorous new growth from these cut-off plants—especially those with the larger spacing—developed large leaves with luxurious mildew, whereas plants allowed to grow for two seasons without being cut back—including those by now large plants with the wide spacing—had relatively small leaves (most of the large leaves of the previous season had dropped), and little mildew.

FUNGI AND INSECTS FOUND MORE ABUNDANT ON TILLED THAN NON-TILLED PLANTS IN CALIFORNIA

Host plant	Pathogen or insect
Coyote brush (Baccharis pilularis) (var. consanguinea)	Powdery mildew (Erysiphe cichoracearum)
	Rust (Puccinia evadens) especially uredinial and telial stages on leaves
	Leaf spot (Phyllosticta baccharidis)
	Gall insect (Rhapalomyia baccharis)
	Aphid (Brachycaudus helichrysi)
Buckeye (Aesculus californica)	Leaf spot and stem canker (Phoma paviae)
Barley (Hordeum vulgare)	Powdery mildew (Erysiphe graminis)
	Leaf rust (Puccinia hordei)
	Scald (Rhynchosporium secalis)
Self heal (Prunella vulgaris)	Powdery mildew (Sphaerotheca sp.)
Live oak (Quercus agrifolia)	Powdery mildew (Sphaerotheca lanestris)
California poppy (Eschholtzia californica)	Powdery mildew (Erysiphe polygoni)
Skunkweed (Navarretia squarrosa)	Powdery mildew (Sphaerotheca sp.)
Plantain (Plantago hirtella)	Leaf spot (Ramularia sp.)
Hop* (Humulus lupulus)	Canker (Fusarium sp. and Phytophthora sp.)

*Hops were not grown with and without tillage. Canker was more abundant on the base of vines from which the lateral shoots were removed, the soil hilled over the fresh wound, and the plants irrigated, than where any one of these normal cultural operations was omitted.

A fortunate chance observation was made following a fire on July 4, 1968, which burned over an area of Coyote Hills Regional Park (Alameda County) dominated by grass and *Baccharis*. The above-ground parts of both kinds of plants were killed, but the dead stems and many of the leaves of *Baccharis* were left in place. Succulent adventitious water sprouts developed at the base of most of these plants, and by October 5 these water sprouts were heavily mildewed, while mildew could not be found on adjacent *Baccharis* outside the fire area.

Results of the six treatments indicate that tillage, nutrients, shade, or even the elimination of competition, were not in themselves singly responsible for the high mildew infection of *Baccharis* observed in this study. Mildew was favored by tenderness of foliage usually associated with large leaves, and these in turn were favored by tillage, wide spacing of plants, forcing of sucker growth, shade, and probably other cultural operations not yet adequately understood. These results are believed to apply to commercial agriculture, but how closely is uncertain. The disease-favoring effect of tillage may be a major cause of the generally greater incidence of disease in cultivated than in wild plants.

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OBSERVATIONS of water repellency in soils made over the past 10 years throughout the world have indicated that this particular problem is more important than had previously been thought. There have been reports that water repellency in golf greens and lawns is responsible for drought conditions even though the grass has had sufficient watering. This condition of water repellency has often been associated with thatch buildup. Nurserymen have noted that many of the soil mixes they use for potting plants are hard to wet.

"Fairy rings" are often associated with drought conditions. There are many varying explanations of their cause. The most commonly held theory is that the fungal hyphae are water repellent and prevent water from getting to the feeding roots of the grass. The dark green ring around the periphery of the dead grass is probably caused by the fact that water moves from the water repellent center of the ring into the more wettable area.

It has been estimated that between 1/30 to 1/60 of the watersheds in southern California are consumed by wildfire each year. From many surveys it appears that about 60 per cent of this burn area is water repellent. During rain storms—even mild storms of low intensity—these areas are more subject to increased runoff and erosion. To reduce the damage to the watershed it has been necessary to find a method which modifies the water repellency of the soil. One such method is through the use of a broad classification of organic chemicals described as "surfactants" or "wetting agents."

The application of wetting agents to water repellent soils allows water to enter into the profile at a faster rate than in the soils not treated. This technique was demonstrated during an experiment in cooperation with the staff of the Pacific Southwest Forest and Range Experiment Station, U.S. Forest Service, near Glendora, Los Angeles County. A water repellent soil, which had previously been burned by a wildfire, was treated with a solution of one part wetting agent to 3,000 parts water. A measurement of runoff and erosion caused by each storm and tabulation of the results at the end of the rainy season revealed that erosion was reduced by 90 per cent, runoff was reduced 30 per cent, and there was a four-fold increase in vegetation on the plots treated with wetting agent.

Many uses for wetting agents are being found in agriculture and therefore further investigation of their various effects