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Conservation Tillage and Vegetable Diseases

Tillage practices directly influence physical and chemical properties of the soil, soil moisture and temperature, root growth, nutrient uptake, and populations of vectors of plant pathogens. These factors in turn may influence the viability and variability of plant pathogens and the susceptibility or resistance of the host. In addition, tillage practices may indirectly influence plant diseases by necessitating changes in the kind, rate, and time of fertilizer application, pesticide use, plant spacing, irrigation, and other cultural practices. Any change in the soil or plant canopy environment may influence the development of disease epidemics.

Conservation tillage—defined as "any tillage and planting system that retains at least 30% residue cover on the soil surface after planting" (5)—has not received as much attention in vegetable production as in agronomic production. Such systems include no-till or slot planting, ridge-till, strip-till, mulch-till, and other reduced or minimum tillage practices. Traditionally, vegetable growers have buried plant debris to reduce the incidence of diseases. Vegetables cover only a small percentage of the nation's cropland and usually are not grown on marginal agricultural land. Also, vegetable growers prefer a smooth, even seedbed free from crop residues in order to obtain a uniform stand (Fig. 1). Because of the high value per acre of most vegetable crops, a uniform stand of high-quality plants is more important than with agronomic crops.

We have been conducting research comparing different tillage practices in vegetable production systems at the Coastal Plain Experiment Station since 1976. Most of the experiments have been in multiple-cropping systems that include both vegetable and field crops under center-pivot irrigation. The soil is loamy sand or sand (85–95% sand), representative of the southeastern coastal plain of the United States. Vegetables grown include snap bean, lima bean, cowpea, squash, cucumber, watermelon, tomato, sweet corn, turnip, collard, and spinach.

Soilborne Pathogens

Populations of *Rhizoctonia solani* in topsoil are probably influenced more by tillage practices than any other soilborne pathogen because the fungus survives in colonized plant debris in the soil. Deep-turning (20–30 cm) the soil with a moldboard plow effectively removes the fungal propagules from the top 10–15 cm of the root zone and buries them 10–30 cm deep (9,17). *R. solani* is sensitive to high levels of CO_2, and populations of the pathogen decline in buried debris. Thus, hypocotyls, crowns, bulbs, or tubers and the bulk of the root system of vegetable crops are not invaded by the buried pathogen until the plants are several weeks old and substantially less susceptible. In contrast, disk harrows, in-row subsoilers, chisel plows, and no-till slot-planters leave most of the plant debris—and the pathogen—in the topsoil (Fig. 2). Thus, seedling tissues may come in contact with the pathogen and be invaded a few days after planting, resulting in poor stands or deformed plants. An exception was reported with potato in North Dakota (3). Stem and stolon lesions were reduced more by disking than by deep-plowing (26 cm) after wheat. Organic matter on the soil surface apparently inhibited the survival or infection potential of *R. solani*.

In our research with vegetables after different crops, tillage practices influenced populations of *R. solani* (primarily AG-4) more after corn, legumes, and vegetables than after green rye (Table 1). Moldboard plowing reduced populations of *R. solani* in topsoil significantly more than did disk harrowing or subsoiling in 75, 16, 12, and 0% of experiments with

Fig. 1. Cucumber after sweet corn with (left) subsoiling and bedding and (right) moldboard plowing.

vegetables after other vegetables, various legumes, corn, and green rye, respectively.

Deep plowing has long been recommended for controlling southern blight or white mold caused by *Sclerotium rolfsii* in subtropical and tropical climates. The pathogen requires a food base in order to grow saprophytically in soil or on the soil surface, and deep plowing buries sclerotia and moves the energy source for the pathogen away from stems and crowns. Deep plowing was more effective than disking in reducing losses to southern blight in carrot (4) and tomato (20). In contrast, sclerotia of *Sclerotinia sclerotiorium* survived deep plowing in Australia. Plowing buried sclerotia and reduced lettuce drop more than did disking, but a second plowing returned viable sclerotia to the surface (10).

Diseases caused by *Pythium* spp. are not influenced greatly by tillage practices. In studies comparing various conservation tillage practices with moldboard plowing, conservation tillage both decreased (9) and increased (17) populations of *Pythium* spp. in topsoil. Tillage practices usually have no significant effect, however, possibly because *Pythium* spp. survive for several months as free oospores in soil within the plow layer, and plowing only returns viable buried oospores to the topsoil.

Little research has been done on the influence of tillage on vegetable diseases caused by *Fusarium solani, F. oxysporum*, and other *Fusarium* spp. In Red Mexican bean in Washington, subsoiling reduced soil compaction and allowed roots to proliferate below the plow layer (2); infection by *F. s.* f. sp. *phaseoli* was not reduced, but the deeper, more vigorous root systems resulted in yields greater than those in moldboard-plowed plots. In another study (1), propagules of *F. s.* f. sp. *phaseoli* were distributed throughout the plow layer (0–30 cm deep) but were rarely found in the subsoil (33–41 cm deep).

In Michigan, no-till reduced Fusarium root and crown rot of asparagus in one of two farms, compared with spring and postharvest disking (14). Tillage caused some mechanical damage to shoots and crowns and may have increased infection by *F. o.* f. sp. *asparagi* or *F. moniliforme*.

Our research at the Coastal Plain Experiment Station gave no indication that tillage practices influence diseases caused by *Fusarium* spp. Cultivars with moderate resistance to Fusarium wilt were used in experiments with watermelon, cowpea, and tomato; Fusarium wilt of spinach has not been identified at the station. Recommended rotational practices with unrelated crops were followed to reduce populations of wilt pathogens. Root rots caused by *F. solani* and other *Fusarium* spp. were negligible in most experiments. Primary or secondary chlamydospores of wilt and root rot *Fusarium* spp. probably survive one to several years in soil, and tillage practices would be less important than crop rotation in disease management.

In most of our studies, tillage methods have not affected populations of plant-parasitic nematodes, the majority of which were in the 0- to 30-cm soil layer (Table 2). The cropping sequence has more of an effect on nematode populations (16), and the susceptibility of the host crop is more important in determining nematode populations and subsequent yield losses. In most of our studies, the tillage system that provided the maximum plant growth and root development favored high nematode populations. Subsoiling may reduce injury from nematodes by allowing the roots to proliferate through a greater volume of soil, as discussed for soilborne pathogenic fungi.

From 1977 to 1980, we grew vegetables in 12 tests with different tillage practices under center-pivot irrigation and with a variety of multiple-cropping systems (17). Moldboard plowing was compared with disk harrowing, chisel plowing, subsoiling under the row and planting, and subsoiling under the row and bedding (ridging). The latter two practices—commonly referred to in the coastal plain as "rip-plant" and "rip-hip," respectively—are sometimes used to prepare land for peanut, soybean, and corn. Each crop was grown in one

Table 1. Populations[a] of *Rhizoctonia solani* in topsoil (15 cm) after various crops with different tillage practices, 1978–1983

	Previous crop			
Tillage practice	**Corn (8)[b]**	**Various legumes (6)**	**Rye (9)**	**Other vegetables (4)**
Moldboard plow	4	6	10	4
Disk harrow	11	15	17	34
Subsoil-plant	13	13	9	22

[a] Colony-forming units per 100 g of oven-dry soil.
[b] Number of experiments conducted.

Table 2. Vertical distribution of plant-parasitic nematodes in the soil as influenced by tillage practice

	Number of nematodes[y] per 150 cm^3 of soil				
	Ring	**Spiral**	**Stubby-root**	**Lesion**	**Sting**
Tillage practice					
Chisel plow	21	3	8	13	14
Disk harrow	24	16	3	9	1
Moldboard plow	14	4	8	7	9
Subsoil-plant	21	4	4	4	16
Soil depth (cm)					
0–10	13 b[z]	16 a	6 b	13 b	14 b
10–20	23 ab	9 b	12 a	20 a	24 a
20–30	38 a	1 c	3 bc	1 bc	3 bc
30–40	7 b	1 c	1 c	0 c	0 c

[y] Ring, *Criconemella ornata*; spiral, *Helicotylenchus dihystera*; stubby-root, *Paratrichodorus minor*; lesion, *Pratylenchus brachyurus*; sting, *Belonolaimus longicaudatus*.
[z] Means followed by different letters are significantly different ($P = 0.05$). Tillage method × soil depth interactions were not significant ($P = 0.05$).

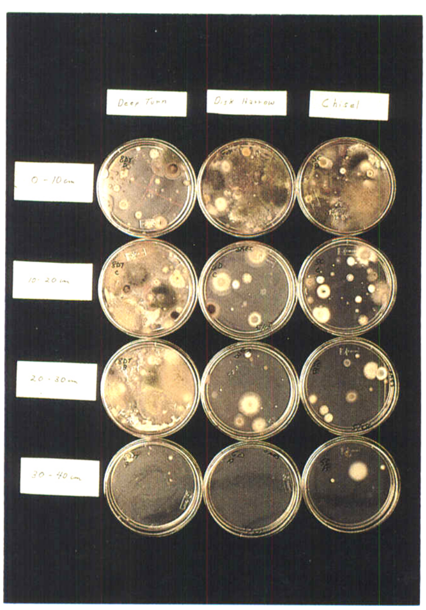

Fig. 2. Colonies of fungi from assays of soil 0-10, 10-20, 20-30, and 30-40 cm deep with moldboard plowing (deep turning), disk harrowing, and chiseling.

quadrant of a 15-acre (6-ha) center pivot, and tillage practices were established in replicated strips just before planting.

Root disease severity was influenced more by the previous crop than by tillage practices (Table 3). Little or no root disease occurred in cucumber (Fig. 3) and turnip, regardless of the previous crop or tillage practice, but planting after legumes usually resulted in moderately severe root disease in tomato and spinach. Moldboard plowing reduced severity of lima bean and cowpea root disease after all crops except cabbage, where root disease severity was slight with all tillage systems. No differences in root disease severity were observed among conservation tillage methods in any vegetable, but differences in soil strength and root growth were noted (13,17).

In separate tests with solid-set irrigation, we compared moldboard plowing, disk harrowing, and subsoiling under the row in 2-year rotations of rye (cover crop)/squash-soybean (double crop)/field corn-snap bean (double crop) and rye (cover crop)/peanut (single crop)/field corn-lima bean (double crop). Very little root disease occurred in three crops of squash grown as spring crops double-cropped with soybean, and no differences were observed among tillage practices. In contrast, moderately severe root disease occurred in snap bean and lima bean grown as fall crops after corn in double-crop systems, and severity was usually greater with disk harrowing and subsoiling than with moldboard plowing (Fig. 4). Most of the root and hypocotyl diseases in legumes were caused by *R. solani* AG-4 and a sterile white basidiomycete that colonized corn debris and invaded the roots and hypocotyls of seedlings (Fig. 5). Cankers caused by the pathogens were much less frequent with moldboard plowing than with conservation tillage.

Postemergence damping-off in snap bean was usually greater with conservation tillage than with moldboard plowing, and occasionally 25–50% of the seedlings were killed. With moldboard plowing, usually fewer than 10% of the plants were killed and plant stands were more uniform. A major difficulty with conservation tillage after corn was the abundant stalk debris. Plant growth was less in fall than in spring snap bean, and pods were produced near the soil surface. Harvesting by machine would have been extremely difficult in disk-harrowed and subsoiled plots because of corn debris. In contrast, rye residues in spring snap bean did not interfere with mechanical harvesting.

Foliar Pathogens

Research comparing the effects of different tillage practices on the severity of foliar diseases in vegetables has been limited. Many pathogens causing leaf, stem, and crown diseases are airborne and are disseminated rapidly for several yards—and sometimes miles—from primary and secondary infections. Compared with conservation tillage, moldboard plowing may greatly reduce the amount of primary inoculum surviving in plant debris on the soil surface and thereby delay the onset of epidemics. Tillage practices would probably have little effect on secondary disease development in most vegetables, however.

Tillage practices may influence soil compaction, nutrient availability and uptake, and root growth and indirectly affect the reaction of plants to infection. Cercospora leaf spot and rust of cowpea were more severe in disk-harrowed plots than in moldboard-plowed ones. Total nutrient efficiency was greater in cowpea grown in moldboard-plowed plots than

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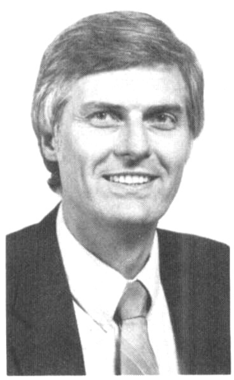

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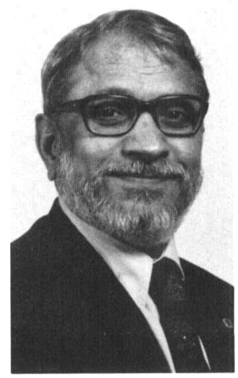

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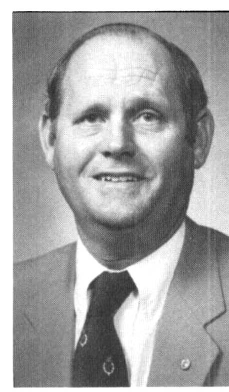

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in disk-harrowed ones (19). At the Coastal Plain Experiment Station, early blight of tomato was more severe with disk harrowing than with moldboard plowing (Fig. 6).

Several bacterial pathogens, e.g., *Pseudomonas syringae* pv. *phaseolicola*, the cause of halo blight of bean, overwinter in plant debris on the surface but not in buried plant debris (11). Conservation tillage could increase the severity of bacterial foliar pathogens if a susceptible host was planted into infested plant debris. Several bacterial pathogens do not survive well in soil, and plowing may help reduce the diseases they cause. Other pathogens, e.g., *Erwinia* spp. and *Pseudomonas* spp. causing soft rots, are ubiquitous in soil, and conservation tillage might have little or no effect on their survival and on disease severity. The influence of tillage practices on yield losses to bacterial diseases of vegetables has not been studied.

The interaction of tillage practices with viral and mycoplasmic pathogens has been studied even less than that with bacterial pathogens. Since many viruses may be transmitted by insects and nematodes and may be present in weed hosts, the influence of the tillage practice on insect and nematode vectors and weed hosts may have a direct bearing on the incidence and severity of viral diseases. Soil and microclimatic conditions in fields provide an inhospitable environment for long-term survival of obligate parasitic pathogens such as plant viruses; the levels of viruses and mycoplasmic agents probably fall very rapidly after vegetables mature. Burial of plant debris may hasten the destruction of the pathogens, especially in multiple-cropping systems.

Crop Rotations

The incidence of foliar diseases with conservation tillage could be greatly influenced by the choice of cropping systems. If an unrelated crop (such as small grain or corn) precedes most vegetable crops, populations of foliar pathogens in debris may decline to very low levels or disappear. If the same crop is grown continuously, however, foliar diseases may reach epidemic levels in subsequent crops a few weeks after planting, regardless of the choice of tillage practice.

Table 3. Root disease severity[a] in vegetables in multiple-cropping systems with different tillage practices under center-pivot irrigation, 1977–1980

		Tillage practice				
Previous crop	**Vegetable**	**Moldboard plow**	**Disk harrow**	**Subsoil-plant**	**Subsoil-bed**	**Chisel plow**
Watermelon	Butterpea (lima bean)	Slight	Moderate	Moderate	···	Moderate
Tomato	Butterpea (lima bean)	Slight	Moderate	Moderate	···	Moderate
Cabbage	Lima bean	Slight	Slight	Slight	Slight	···
Sweet corn	Cowpea	Moderate	Moderate	Moderate	···	Moderate
Field corn	Cowpea	Slight	Moderate	Moderate	···	Moderate
Tomato	Cucumber	Slight	Slight	Slight	Slight	···
Sweet corn	Cucumber	None	Slight	Slight	Slight	···
Turnip	Tomato	Slight	Slight	Slight	···	Slight
Soybean	Tomato	Moderate	Moderate	Moderate	···	Moderate
Soybean	Spinach	Slight	Moderate	Moderate	Moderate	···
Peanut	Spinach	Slight	Slight	Slight	Slight	···
Soybean	Turnip	Slight	Slight	Slight	···	Slight
Cucumber	Turnip	Slight	Slight	Slight	Slight	···

[a] None = 1%, slight = 2–10%, and moderate = 11–50% of roots and hypocotyls discolored or decayed.

When we planted a fall crop of lima bean immediately after a spring crop of lima bean under center-pivot irrigation, stem anthracnose was so severe that the second crop had to be abandoned (Fig. 7). The plants in the second crop were infected with *Colletotrichum truncatum* soon after emergence, even though residues from the first crop were buried by moldboard plowing. The disease could not be controlled once the plants were infected. Similarly, leaf spots of turnip were more severe in intensive cropping systems when both fall and spring crops were grown for leafy greens each year than when only one crop was grown in the spring (18). Since no winter crop was grown, leaf spot pathogens apparently survived from the fall crop on plant debris, even though the soil was moldboard-plowed each year before turnip was planted in the spring.


Fig. 3. Intensity of foliar and root diseases in cucumber after tomato was slight with either (left) moldboard plowing or (right) in-row subsoiling and bedding.

Fig. 4. Incidence of damping-off in snap bean after corn was (A) 6% with moldboard plowing and (B) 25% with disk harrowing.


Fig. 5. Hypocotyl cankers caused by *Rhizoctonia solani* AG-4 and a sterile white basidiomycete in snap bean after corn with in-row subsoiling.

Continuous cropping of two or three crops of cucumber per year has been practiced in the southeastern United States, but gummy stem blight induced by *Mycosphaerella citrullina* may be severe if other crops are not rotated with cucumber to reduce primary inoculum (15). When a grower in Georgia harvested a spring crop of cantaloupe, disked the plant residues, and planted a second crop of cantaloupe, gummy stem blight invaded the foliage and fruit (Fig. 8) of the second crop, destroying most of it. Moldboard plowing probably would have reduced, but not eliminated, the severity of gummy stem blight.

Soil is manipulated more often in multiple-cropping systems than in single-cropping systems, and foliar pathogens may disappear faster when two or three unrelated crops are grown per year. Thus, growing a crucifer, a cucurbit, and a legume every year might be possible with conservation tillage in a multiple-cropping system, whereas growing related crops in a single-cropping system might require a rotation of two, three, or more years. Damage to vegetables is frequently increased when two crops of vegetables are grown every year. In a 14-year study in Connecticut, yields of lettuce, carrot, sweet corn, spinach, beets, and cabbage were lower with intensive rotations of two successive crops of vegetables per year than when vegetables were alternated with green manure crops of rye, vetch, or soybean (6).

Crop rotation and cultivar selection are beneficial in managing populations of plant-parasitic nematodes (7,8). Nematode population dynamics were studied in an integrated pest management program under irrigation with three intensive multiple-cropping systems under moldboard tillage (8). Numbers of root-knot nematode (*Meloidogyne* spp.) juveniles were lowest in the sweet corn-soybean-wheat-soybean-spinach cropping system, intermediate in the turnip-peanut-cucumber-turnip-cucumber-soybean system, and highest in the turnip-field corn-southern pea system. Numbers of *M. hapla* juveniles increased on peanut in the turnip-peanut-cucumber-turnip-cucumber-soybean system and declined to near or below detectable levels on cucumber after turnip. Numbers of *M. incognita* juveniles increased on corn in August and on the southern pea cultivar Pinkeye Purple Hull in October or November in the turnip-field corn-southern pea system. Numbers of these nematodes were greater on Pinkeye Purple Hull than on the root-knot-resistant southern pea cultivar Worthmore. Turnip, wheat, sweet corn, and spinach were poor hosts for *M. incognita* and *M. hapla*.

Phytotoxins

The possibility of phytotoxins from decomposing residues causing root necrosis and stunted, deformed plants is also increased by conservation tillage. Lettuce is sensitive to decaying crop residues, and root disease and stunting have been reported widely in intensively cropped lettuce (15). Because phytotoxins are more common in decomposing

Fig. 6. Early blight of transplanted tomatoes after lima bean was more severe with (A) disk harrowing than with (B) moldboard plowing.

residues and adjacent soil than in soil free from decomposing residues (12), tillage practices that place decomposing residues in contact with seeds and seedlings may increase susceptibility to root pathogens. On the other hand, conservation tillage could enhance populations of beneficial microorganisms and the biological control of pathogens.

Future Outlook

Vegetable growers will probably continue to rely on moldboard plowing as a convenient way to reduce many foliar and root diseases, especially in short-term rotations. Also, nematicides and other pesticides are easier to apply after moldboard plowing than with conservation tillage. Where producers are able to plant vegetables in long-term rotations of unrelated crops, however, conservation tillage may be successful. Planting spring vegetables into small grain or grass residues with slot planters is possible for many growers and may be the only feasible method of producing vegetables on marginal, erodible land.

The influence of tillage methods on the epidemiology of most vegetable diseases is unknown, and data on plant diseases have not been recorded in most investigations of tillage practices with vegetables. Plant pathologists can extrapolate from greenhouse and microplot tests with organic amendments, but large-scale tests with tillage equipment similar to that used by producers will be necessary to determine what happens in the field.

Fig. 7. Severe stem anthracnose of lima bean after lima bean with (left) in-row subsoiling and (right) moldboard plowing.

Fig. 8. Gummy stem blight of cantaloupe from second crop planted after spring crop of cantaloupe and disk harrowing of plant residues.

Tillage practices are probably irrelevant for the numerous diseases caused by pathogens that survive in soil for years, including *Fusarium*, *Verticillium*, and bacterial wilt pathogens and many plant-pathogenic nematodes. Because of the interaction of compaction, plant nutrition, and microbial competition and antagonism on root growth and plant vigor, the influence of no-till, chisel plowing, or subsoiling on such diseases may be different than expected.

The effect of phytotoxins in decomposing residues on root growth and root disease severity is controversial, and what happens in in vitro and greenhouse tests may not reflect what happens in fields. Nevertheless, there are abundant records of difficulties growers have experienced when vegetables, especially lettuce, were planted in proximity to a variety of plant residues. Vegetables cannot be grown profitably for once-over machine harvest if plant stands are poor and growth is nonuniform. If plant scientists can unravel the complex processes involved in the influence of residue decomposition on root growth, growers may be able to enjoy the benefits of conservation tillage without the detriments. Organic matter frequently is a plus in increasing populations of saprophytic fungi and bacteria that antagonize and parasitize root pathogens and provide a protective shield for roots. If conservation tillage can aid in biological control, it may be superior to moldboard plowing in many instances. Gardeners and homeowners are successfully using forms of conservation tillage in organic gardening. Organic gardening with compost coupled with crop rotation and resistant cultivars will probably become much more common in small garden plots.

Acknowledgments

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