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Strip-Tillage in California's Central Valley

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INTRODUCTION

Strip-tillage is a form of conservation tillage that clears crop residues in a narrow zone of soil and loosens subsoil layers prior to planting. This tillage zone is typically 8 to 12 inches wide and 2 to 14 inches deep, depending on the implement that is used (fig. 1). Strip-tillage decreases both the volume of soil that is disturbed and the amount of dust that is typically generated in intercrop tillage, and it also reduces fuel, labor, and equipment costs when compared with traditional broadcast tillage. It also provides opportunities for band application of surface-incorporated herbicides and fertilizers at different depths prior to seeding. Because only a relatively small volume of soil is tilled using strip-tillage, it is often also called "zone" or "vertical" tillage. This tillage system requires a strip-tillage implement as well as several other key changes in an overall cropping system to be successful.

WHERE IS STRIP-TILLAGE USED?

Strip-tillage systems were developed several decades ago and are now widely used in the coastal plains region of the southeastern United States for crops such as cotton, corn, and peanuts as a means to break up the naturally settling and consolidating subsoil layers that are routinely formed in this area. In these systems, the objective of strip-tillage is to loosen compacted subsoil zones while leaving the soil surface and crop residues relatively undisturbed (fig. 2). Strip-tillage also is used in irrigated row crop production systems in eastern Colorado and western Nebraska (Smith and Pearson 2004), for sweet corn and bean production in western Oregon (Luna and Staben 2003), rainfed corn and soybean production in the Midwest, and for a variety of row crops in Texas.

Strip-tillage was first introduced in California for melon production in 1998, for processing tomato production in cover crop surface mulches in 2001 (Mitchell et al. 2004) (fig. 3), and for cotton under clean-till conditions. Initially, PTO-powered rototiller-type implements were used with success for both direct-seeded melons and corn and for transplanted tomatoes in a number of research station and farmer field evaluations. Subsequently, ground-driven strip tillers were introduced for processing tomato production in both cover cropped and organic fields (Madden et al. 2004). More refinements

Figure 1. Strip-tilling into barley cover crop before cotton planting, Riverdale, California, 2001. *Photo:* Jeff Mitchell.

Figure 2. Strip-tillage cotton in rolled rye cover crop, Auburn, Alabama, 2004. *Photo:* Jeff Mitchell.

Figure 3. Basic components of early prototype strip-till implement used in California, including residue-cutting coulter, subsoiler shank, and clod-busting rolling basket, Five Points, California, 1996. *Photo:* Jeff Mitchell.

and variations on the strip-till tomato theme with both rotary-powered and ground-driven strip-tillage equipment have been made in recent years.

Several thousand acres of both fresh market and processing tomatoes have been produced in recent years in western Fresno County using strip-tillage following triticale and barley cover crops. In these systems, cover crops break up tomato monocultures and are seeded and irrigated up generally in late October or early November, and terminated using glyphosate (a broad-spectrum postemergence herbicide) in February and March to avoid problems that can result from very high biomass cover crop surface residues. A variation on the ground-driven coulter or subsoiling shank strip-tillers that are used in California dairy cropping systems is a 3-row 60-inch strip-tiller used for sweeping furrows clean before transplanting processing tomatoes in a chopped cover crop (fig. 4).

BENEFITS OF STRIP-TILLAGE

A range of economic and natural resource conservation benefits may result from strip-tillage systems. Because strip-tillage uses fewer intercrop tillage passes or operations strip-till than do traditional tillage systems, actual tillage, or "land preparation," costs strip-till are lower. In a 2002 farm evaluation of strip-tillage forage corn production near Modesto, California, which was the first documented experience with strip-till corn in California, costs for strip-tillage corn establishment were about 54 percent lower than costs of traditional preplant soil preparation. Not only are seedbed preparation costs lower with strip-tillage, but the actual requirements for farm labor and the time required for tillage between crops may also be lower, too. The success of strip-tilled corn to date, however, has relied on the use of Roundup Ready (RR) corn, which would include at least one application of glyphosate early in the season, sometimes followed by a second application midseason depending on weed pressure.

The growing attractiveness of strip-tillage systems for California dairymen rests on the ability of these systems to cut production costs and reduce the time between successive forage crops, allowing more opportunities for triple-cropping, the sequential production of three crops within a given calendar year. Reduced tillage between winter forage and corn has also provided more time after corn for spreading and incorporation of manure prior

Figure 4. Ground-driven modified Orthman 1-tRIPr strip-tiller implement tilling in cover crop in center of tomato beds and sweeping out furrows for irrigation, Davis, California, 2006. *Photo:* Dennis Bryant.

Figure 5. Downwind sampling of PM10 at Burrell, California, dairy, 2003. *Photo:* Jeff Mitchell.

Figure 6. Orthman 1 tRIPr strip-tiller hooked up with planter for "one-pass" strip-tilling and planting, Kerman, California, 2006. *Photo:* Jeff Mitchell.

to planting winter forage, or for fall tillage prior to spring-planted crops such as cotton or tomatoes. With recently implemented waste discharge regulations that limit field applications of dairy waste nutrients to 140 to 165 percent of expected crop removal (see CVRWQCB 2007), triple-cropping of forages may become an important cropping system for dairies with limited forage production acreage. This system permits the production of more forage on the same acreage in a given time. Shortened intervals between crops also facilitates the capture of nitrogen before it becomes subject to leaching.

Strip-tillage can dramatically reduce the amount of dust that is generated by tillage and soil preparation operations in dairy forage systems. From 2001 through 2004, PM10 (particulate matter $\leq$ 10 microns in aerodynamic diameter) downwind emissions from tillage operations between crops were quantified in no-till and strip-till fields at two San Joaquin Valley (SJV) dairies relative to traditional tillage (Madden et al. 2008). PM10 emissions were reduced by 65 to 90 percent using strip-tillage for corn and no-till winter forage establishment (fig. 5).

Finally, strip-tillage systems also can preserve earthworms that burrow, decompose surface residues, cycle nutrients, and create macropores in the soil. Studies of strip-till corn production in Oregon have reported higher populations of the nightcrawler worm *(Lumbricus terrestris)*, compared with traditional tillage systems (Luna and Staben 2003). A number of California producers have begun to report increases in anecic, or horizontal-burrowing, worms in strip-till corn and tomato systems.

PROBLEMS WITH STRIP-TILLAGE

The greatest problems that have been encountered with strip-tillage in California dairy forage systems are the difficulties in achieving uniform crop stands and managing weeds. Work by Mike Petersen in Greeley, Colorado, has shown that corn root growth can be reduced by roughly a third at 55 days after planting with a misalignment between the strip-tiller and the planter of as little as 4 inches (Reichenberger 2007). Assuring that the corn planter tracks or follows precisely in strip-tilled zones is essential and can be accomplished either by using the same global positioning system (GPS) for both strip-tillage and planting operations, or simply by having the planter hooked up to the strip-tiller and performing both operations together in one pass (fig. 6).

Figure 7. Strip-tilled forage corn stand, Frank Gwerder Dairy, Modesto, California, 2007. *Photo:* Jeff Mitchell.

At ten San Joaquin Valley farms in 2007, we compared stand establishment following strip-tillage with plant stands achieved with traditional tillage (fig. 7). Forage corn producers using strip-tillage tend to seek populations of between 28,000 and 36,000 plants per acre. While there were slight differences in stands achieved in strip-tilled fields relative to traditional tilled fields, particularly at a site in Turlock where strip-tilling was done before preirrigating and at a site in Hanford where a higher seeding rate was used in the traditional till field, generally adequate stands have been achieved using strip-till.

Early season weed control is critical for successful strip-till production because the entire soil surface is not tilled. Weeds and weed seeds in the inter-row spaces that would otherwise be buried in a conventional broadcast tillage are not disturbed or displaced in a strip-tillage system, causing increased weed densities early in the season. However, buried weed seeds are also not brought to the surface strip-till. To date, weed management in San Joaquin Valley triple-crop systems has generally been accomplished by use of Roundup Ready corn varieties and by in-season application of glyphosate. Data from our experiments at 8 locations in the San Joaquin Valley in 2007 indicated that fewer weeds emerged in the strip-till than in the traditional tillage plots at several locations. All of these locations had Roundup Ready varieties of corn and glyphosate was applied once after corn emergence. The higher weed densities in strip-tillage plots were noticed in fields where the glyphosate application was delayed. Most of the weed population at these sites was comprised of volunteer cereals from preceding rotations and pigweeds (*Amaranthus* spp.). Preventing weed competition during the first few weeks of corn establishment is very important to avoid yield losses. In the current strip-till systems in the San Joaquin Valley, the norm is one application of glyphosate after corn planting. Thus, proper timing of this herbicide application is very important. Studies should be conducted to ascertain the effect of the timing of glyphosate application on forage yield under strip-tillage systems. Also, the use of preemergence herbicides and alternative weed management strategies also should be explored.

Over time, with less deep tillage in a strip-till system and as more residues cover the soil, fewer surface weeds may emerge in strip-tillage systems than emerge under traditional tillage. But the primary means for weed control in strip-till systems in these dairies are timely glyphosate applications with Roundup Ready corn and cultivation when weeds are small.

Timing of Strip-Tillage

Timing is a critical determinant of the success of strip-tillage systems. In general, strip-tillage is most effectively performed when the soil is dry enough to allow shattering of the subsoil profile, but not so dry as to produce large surface clods of soil that do not permit even and consistent seeding. Research at the USDA Agricultural Research Service Soil Dynamics

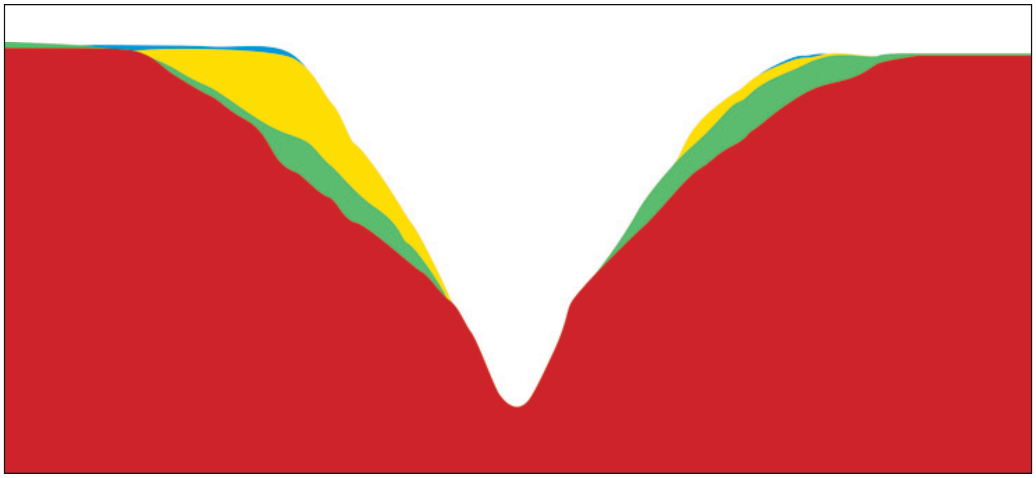

Figure 8. Model of soil cross-section showing extent of soil-loosening when strip-tilling is done when soil is wet (yellow) or dry (green). Red indicates soil that is not affected by the strip-tillage shank. Courtesy Randy Raper and Francisco Arriago, USDA ARS Soil Dynamics Laboratory, Auburn, Alabama, 2007.

Laboratory in Auburn, Alabama, has demonstrated that a wider area of soil is loosened when dry soil is strip-tilled than when wet soil is strip-tilled, but this must be balanced by the need to provide satisfactory seeding conditions (fig. 8). Timing of the strip-tillage operations ultimately depends on the specific implement that is available, whether the strip-tiller is hooked directly to the planter, and the need to seed at a certain time in order to achieve yield goals.

Strip-tillage is most effectively accomplished when the soil in the vertical zone that is to be tilled is relatively dry, but not so dry that the strip-till implement brings up large soil clods or bends under the high resistance that can exist in very dry conditions. Conversely, strip-tillage is best done when the soil is somewhat moist, but not so wet that compacted layers are not shattered or broken up. Thus, in forage corn production systems, strip-tillage would generally be done immediately following winter small grain chopping and before preirrigation for corn.

Dairy Forage Production and Strip-Tillage

For strip-tillage to become a sustainable management option in dairy forage production systems, several issues must be addressed and resolved. The distance between irrigation berms that are typically used to facilitate water movement across a field and the actual size of these berms should be determined and set out in advance to permit optimal seeding and harvesting of all crops in a forage rotation. When strip-tillage and no-tillage corn seeding was first introduced into San Joaquin Valley forage fields, farmers tended to avoid planting the berm areas because they did not think it would be successful. By not planting berm areas, however, a sizeable portion of the field remains unproductive. Strip-till and no-till corn farmers now use different strategies to address this problem. Planting or strip-tilling and then planting directly over the berms can be done if existing berms are relatively shallow or low. Another approach is to reconfigure fields with relatively narrow berms that permit GPS-enabled planting and the strip-till planting directly up to the base of the berm. The narrow berm is left unplanted, but planting is done on all but the top of the berms throughout a field.

Strategies that reduce or avoid the risk of soil compaction will be required for successful long-term conservation tillage dairy forage systems. By reducing the number of tractor traffic trips across a field, less compaction will occur. In addition, avoiding harvesting when the soil is wet, and subsoiling, or breaking up compacted subsoil layers by ripping, may reduce the risk of compaction.

Dairy Manure Application and Strip-Tillage

When strip-tillage is used in San Joaquin Valley dairies following winter forage chopping and before summer corn seeding, dairymen typically apply solid manure materials before seeding corn. Experience suggests that applying composted manure ahead of strip-tilling seems to be better than applying raw manure. Composted manure is lighter and more

Figure 9. Five-row rotary strip-tiller tilling center of processing tomato beds prior to transplanting, Firebaugh, California, 2006. *Photo:* Jeff Mitchell.

Figure 10. Bigham Brothers Terratill strip-tiller implement, showing residue-cutting coulters, subsoiling shanks, and clod-busting baskets. *Photo:* Jeff Mitchell.

uniform in nitrogen content, is less odiferous, has less viable weed seed, and will be mixed more efficaciously into the surface soil with the strip-tiller. Spreading raw manure can leave large clumps on the soil surface that can present problems for seeding, in addition to adding large amounts of weed seed. Local air quality regulations governing manure applications may also apply.

STRIP-TILLAGE EQUIPMENT

A variety of strip-tillage implements have been developed and are now used for different cropping systems in California. These implements tend to be either PTO-powered rotary tillers that have been used primarily in processing tomato fields or ground-driven coulter or subsoiling shank implements that have been most commonly and widely used in corn forage systems. Rotary strip-tillers are essentially modified rototillers that till only the areas into which seeding or transplanting is done (fig. 9). Herbicide and starter fertilizers also have been applied and incorporated with these rotary strip-tillers. Strip-tillage implements that are used in California dairy cropping systems for corn planting generally include a residue-cutting coulter or blade, a subsoiling shank, and a tool or mechanism for breaking up soil clods and creating smooth seedbed conditions (fig. 10).

While there are variations in the types of strip-tillers that are currently available in terms of the draught energy that is required to pull them, in general, about 30 horsepower is needed for each row unit or subsoiling shank. This horsepower requirement, however, depends on the design, weight, and other features of the strip-tiller, as well as on the desired depth of tillage. Soil water content is also a factor: more energy is needed in dry soil.

CALIFORNIA STRIP-TILLAGE: CURRENT STATUS

The California Conservation Tillage Workgroup, a diverse group of over 1,500 researchers, extension educators, conservationists, farmers, and private sector partners has tracked an increase in the use of strip-tillage at the commercial scale in 2007 (Mitchell et al. 2007). Over 20 farm field demonstration evaluations of strip-tillage at San Joaquin Valley dairies were underway in 2007 by workgroup affiliates. Updates and additional information on these evaluations are available at the workgroup's Web site, http://groups.ucanr.org/ucct/.

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English	Conversion factor for English to Metric	Conversion factor for Metric to English	Metric
inch (in)	2.54	0.394	centimeter (cm)
foot (ft)	0.3048	3.28	meter (m)
acre (ac)	0.4047	2.47	hectare (ha)
pound (lb)	0.454	2.205	kilogram (kg)
ton (T)	0.907	1.1	metric ton (t)
pound per acre (lb/ac)	1.12	0.89	kilogram per hectare (kg/ha)
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