STRIP-TILLAGE IN CALIFORNIA'S CENTRAL VALLEY FORAGE PRODUCTION SYSTEMS

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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 – 14 inches deep depending on the implement that is used. Strip-tillage decreases both the volume of soil that is disturbed and the amount of dust that is typically generated in intercrop tillage and reduces fuel, labor and equipment costs when compared to 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 for using strip-tillage is to loosen compacted subsoil zones while leaving the soil surface and crop residues relatively undisturbed. 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 (Personal Communication, J. Young).

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) 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 and used for processing tomato production in both cover cropped and organic fields (Madden et al., 2004). More refinements 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 are used to break up tomato monocultures and are seeded

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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 / subsoiling shank strip-tillers that are used in California dairy cropping systems is a 3-row 60" strip-tiller used for for sweeping furrows clean before transplanting processing tomatoes in a chopped cover crop.

Benefits of strip-tillage. A range of economic and natural resource conservation benefits may result from use of strip-tillage systems. Because the number of intercrop tillage passes or operations is reduced in strip-tillage relative to traditional tillage systems, actual tillage, or "land preparation" costs associated with strip-tillage are lower than with traditional tillage. In a 2002 farm evaluation of strip-tillage forage corn production near Modesto, CA, 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 (Personal communication, Mike Nutcher, Modesto, CA). 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 reduced with strip-tillage. 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 mid-season 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 been done to provide more time after corn for spreading and incorporation of manure prior to planting winter forage again, 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% - 165% of expected crop removal (http://www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/general_orders/r5-2007-0035.pdf), 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 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. PM10 emissions were reduced by 65 – 90% using strip-tillage for corn and no-till winter forage establishment (Madden et al., 2008).

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 to 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 (Personal communication, J. Sanchez and S. Iest).

Problems with strip-tillage. The greatest problems that have been encountered with strip-tillage in California dairy forage systems are the difficulties achieving uniform crop stands and managing weeds. Work by Mike Petersen in Greeley, CO, has shown that corn root growth can be reduced by roughly a third at 55 days after planting with misalignment between strip-tiller and 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 GPS (Global Positioning System) system 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 (Photo 1.

At ten San Joaquin Valley farms in 2007, we compared stand establishment following strip-tillage with plant stands achieved with traditional tillage (Photo 2) Forage corn producers using strip-tillage, tend to seek plant populations between 28,000 and 36,000. 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 in a strip-till operation. 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 thus causing increased weed densities early in the season. However, on the other hand, buried weed seeds are also not brought to the surface as there is no soil inversion in the inter-row space with strip-tillage. To date, weed management in San Joaquin Valley triple crop systems has been generally accomplished by use of RoundUp Ready corn varieties and in-season application of glyphosate. Data (not shown) from 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 glyphosate-tolerant (*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 comprised of volunteer cereals from preceding rotations and pigweeds (*Amaranthus* sp.). 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 need to be conducted to ascertain the effect of glyphosate application time on forage yield under strip-tillage systems. Also, the use of pre-emergence herbicides and alternative weed management strategies also need to 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 relative to traditional tillage. But the primary means for weed control in strip-till systems in these dairies are timely glyphosate applications with RR corn and the use of 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 relatively dry 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 Laboratory in Auburn, AL has demonstrated that a wider area of soil is loosened when dry soil is strip-tilled than wet soil, but this must be balanced by the need to provide satisfactory seeding conditions. Timing of the strip-tillage operations ultimately depends on the specific implement that is available, whether or not 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 resistances 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 pre-irrigation for corn.

Strip-tillage dairy forage production considerations For strip-tillage to become a sustainable management option in dairy forage production systems, several issues need to 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 needs to 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, growers 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-tillage 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 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 applications 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. Applying composted manure ahead of strip-tilling seems to be better than applying raw manure (Personal communication, D. Giacomazzi, Hanford, CA). Composted manure is lighter and more 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 than raw manure. Spreading raw manure can leave large clumps on the soil surface which 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 / 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 (Photo 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 (Photo 3.

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 (HP) is needed for each row unit or subsoiling shank. This HP requirement, however, varies depending 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 influencing the draught energy that is required to pull a strip-tillage implement through the soil; more energy is needed in dry soil.

California strip-tillage -- Current status. The California Conservation Tillage Workgroup, a diverse group of over 1500 researcher, extension education, conservationist, farmer, and private sector partners (Mitchell et al., 2007), has tracked an increase in the use of strip-tillage at the commercial scale in 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 website http://groups.ucanr.org/ucct/.

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Photo 1 – Orthman 1 tRIPr strip-tiller hooked up with planter for "one-pass" strip-tilling and planting, Kerman, CA, 2006.

Photo 2.
Strip-tilled forage corn stand, Frank Gwerder Dairy, Modesto, CA, 2007.

Photo 3.
Bigham Brothers Terratill strip-tiller implement close-up showing residue-cutting coulters subsoiling shanks and clod-busting baskets.