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Cover Crops for Weed Management in Southern Reduced-Tillage Vegetable Cropping Systems

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With growing agricultural demands from both conventional and organic systems comes the need for sustainable practices to ensure long-term productivity. Implementation of reduced- or no-till practices offers a number of environmental benefits for agricultural land and maintains adequate yield for current and future production. Concerns over satisfactory pest control options, particularly weed control, have contributed to the slow adoption of conservation practices in many areas. To identify effective alternative weed management options for use in conservation systems, research in the Southeast has continued to evaluate the use of cover crops in conjunction with reduced-tillage practices. A number of cover crop species, including cereal grains, legumes, and Brassicaceae species, that have potential to suppress weeds through direct crop interference or allelopathic potential have been investigated. Many recent research projects in the Midsouth and southeastern United States have assessed the success of cover crops in reduced-tillage row crop settings with promising outcomes in some systems. However, continued research is necessary to identify appropriate cover crop and tillage systems for use in other agricultural settings, such as vegetable crops and organic production systems.
Key words: Alternative weed control, conservation agriculture.

Con el incremento en la demanda de productos agrícolas tanto de sistemas convencionales como orgánicos, viene la necesidad de prácticas sostenibles que aseguren la productividad a largo plazo. La implementación de prácticas de labranza reducida o cero ofrece un número de beneficios ambientales para la tierra agrícola y mantiene rendimientos adecuados para la producción actual y futura. La preocupación con respecto al control satisfactorio de plagas, particularmente de malezas, ha contribuido a la lenta adopción de prácticas de conservación en muchas áreas. Con el objetivo de identificar opciones alternativas para el manejo de malezas, las investigaciones en el Sureste han continuado para evaluar el uso de cultivos de cobertura en combinación con prácticas de labranza reducida. Se han investigado varias especies como cultivos de cobertura, incluyendo cereales, leguminosas y especies Brassicaceae, que tienen el potencial de suprimir malezas mediante la interferencia directa del cultivo o por su potencial alelopático. Muchos proyectos de investigación recientes en el Sur medio y en el Sureste de los Estados Unidos han evaluado el éxito de cultivos de cobertura en cultivos extensivos y bajo labranza reducida con resultados promisorios en varios sistemas. Sin embargo, se necesita que la investigación continúe para identificar cultivos de cobertura apropiados y sistemas de labranza para el uso en otros sistemas agrícolas, tales como vegetales y sistemas de producción orgánica.

Current U.S. consumption and use of vegetables is estimated to be slightly less than 200 kg per person annually with over $13 billion a year spent on vegetables by residents in southern states (U.S. Department of Agriculture-Economic Research Service 2012). With vegetable demand expected to continue to increase slowly (Thornsbury and Jerardo 2012), vegetable production likely will experience continued growth in the southeastern United States. In order to preserve farm resources and reduce the need for external inputs which increase producer costs (Singh et al. 2005), sustainable vegetable production practices must be implemented.

A number of management practices have been identified as tools to improve production sustainability. Among these are reduced tillage (RT), cover cropping, crop rotation, intercropping, and water management (Singh et al. 2005). RT practices, in particular, can improve soil organic matter and maintain crop yield in the future (Phatak et al. 2002). However, implementation of RT in vegetable productions can be challenging due to the loss of weed control provided by tillage and cultivation.

Reduced Tillage. The adoption of RT or no-tillage (NT) systems can improve multiple environmental aspects of agricultural land, particularly concerning erosion and runoff (Price et al. 2011). NT operations have also been shown to improve soil quality and reduce production expenses; however, in some instances, complete elimination of tillage has not been feasible due to soil compaction (Busscher and Bauer 2003; Schomberg et al. 2006; Triplett and Dick 2008). In these cases RT, such as strip-tillage (zone tillage), offers many of the benefits of NT operations with reduced surface disturbance while still providing a narrow cultivated seed bed for planting and reduced soil compaction from in-row subsoiling (Raper et al. 1998; Torbert and Reeves 1994). Integrating cover crops into these systems as ground cover after crop planting can further reduce soil erosion and water runoff while providing a level of weed control through physical and allelopathic means (Hartwig and Ammon 2002; Reeves 1994). Strip-tillage, in particular, has been identified as an alternative to employ with cover crops to replace conventional tillage in situations in which soil temperatures is reduced due to residue cover or development of a hardpan is a concern (Bottenberg et al. 1999).

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In the southern United States, RT systems with high-residue cover crops have been successful for weed control in conventional cotton and soybean research (Norsworthy et al. 2011; Price et al. 2006; Reeves et al. 2005). Results of these studies showed increased weed suppression from high-residue cereal covers in strip tillage systems when compared to fallow systems. These experiments also reported crop yields equal to or greater than fallow systems when utilizing a high biomass-producing cover crop such as rye (*Secale cereale* L.). Other cover crops evaluated in these studies such as wheat (*Triticun aestivum* L.) and turnip (*Brassica rapa* L.) were less successful overall compared to other cover crops due to reduced weed inhibition or reduced yield from cover crop allelopathy.

Although RT row crop production with cover crops has been documented, vegetable producers, both conventional and organic, have largely avoided implementing these practices because of concerns over increased insect and disease pressure as well as a dependence on tillage and cultivation practices for adequate weed control (Phatak et al. 2002). For organic producers, the inability to use herbicides makes tillage practices an even more critical aspect of weed suppression. Research has been conducted with these systems in regions such as California and the Northeast with successful outcomes; however, experimentation remains limited in southeastern organic vegetables (Madden et al. 2004). In the available publications for this region, variable weed control response has been reported; although, these systems have been shown to be economically feasible in some vegetable production systems (Chellemi and Rosskopf 2004; Morse 2000; Mulvaney et al. 2011; Treadwell et al. 2007).

Although RT offers many environmental and economic benefits, one major drawback to utilizing less tillage is the loss of weed control. In many vegetable production systems, particularly organic production, limited or no herbicides are available for use, leaving growers to rely on tillage and subsequent cultivation to achieve sufficient weed control (Fernandez et al. 2012; Mulvaney et al. 2011; Walters and Young 2012). To effectively maintain weed suppression in RT vegetables, multiple weed control strategies can be utilized as alternatives to intensive tillage and herbicides including mulches, cover crops, soil solarization, flaming, and biological control agents (Singh et al. 2005). Specifically, ground covers, such as mulch and cover crop residue, offer a level of weed suppression when utilized in conjunction with RT.

Weed Control with Ground Covers. Conventional as well as organic vegetable production often employs some type of mulch system to help suppress in-row weed emergence. Polyethylene mulch is commonly used in both for a number of benefits, including weed suppression, more rapid crop growth, and plant protection from disease (Bangarwa et al. 2009; Locascio et al. 2005; Warnick et al. 2006b). Although plastic mulch is allowed in organic systems, several disadvantages of polyethylene mulch, such as removal expense, increased runoff, and soil erosion, have encouraged research efforts to identify more sustainable mulch materials for use in vegetable production (Law et al. 2006; Rice et al. 2001). Plastic mulches also generally require tillage to produce a flat surface and to bury the edges of the mulch to keep it in place during the season.

A number of organic mulches have been evaluated in the Southeast as alternatives to plastic mulches, which are more compatible with RT systems. Although the use of organic mulches may reduce soil temperature in comparison with plastic, soil moisture conservation, reduced runoff, improved soil quality, and low removal costs have made organic mulches such as straw, wood chips, and compost potential mulch options in organic production (Feldman et al. 2000). To this end, Law et al. (2006) in Kentucky and Mulvaney et al. (2011) in Alabama have reported effective weed suppression in herbicide-free vegetable production with surface-applied mulches including straw, wood chips, and perennial weed cuttings. Additional alternative mulches, such as hydraulic and foam mulches, have been developed for use in organic systems and have potential for successful weed control (Masiunas et al. 2003). Hydramulch, a type of cellulose fiber–based hydraulic mulch applied as a slurry, has been tested in Florida and shows promise for weed control in organic production of vining plants where nutsedge (*Cyperus* spp.) is not a problematic weed (Warnick et al. 2006a).

Cover Crops. Weed suppression also can be achieved in vegetable production with a variety of cover crops grown prior to the vegetable crop. Cereal grains, legumes, and mustards are common cover crops shown to be beneficial in vegetable systems for multiple purposes such as nematode suppression, nitrogen source, improved soil quality, and weed control (Peoples et al. 1995; Wang et al. 2008). Common cover crops include fall-planted species such as cereal rye, crimson clover (*Trifolium incarnatum* L.), vetch species (*Vicia* spp.), and radish (*Raphanus* spp.); summer covers can include soybean [*Glycine max* (L.) Merr.], velvetbean (*Mucuna pruriens* L.), sudangrass and sorghum × sudangrass hybrids [*Sorghum bicolor* (L.) Moench ssp. *drummondii* (Nees ex Steud.) de Wet and Harlan], and cowpea (*Vigna unguiculata* L.) (Creamer and Baldwin 2000; Sustainable Agriculture Research and Education [SARE] 2007).

Traditionally in organic systems, summer or winter cover crops are incorporated into the soil through primary tillage before crop seeding or transplanting (Norsworthy et al. 2007; Treadwell et al. 2007; Wang et al. 2008). Weed emergence is reduced during the growing season of the cover crop as well as through the release of allelopathic compounds, if produced by the species, after soil incorporation (Brennan and Smith 2005; Treadwell et al. 2007). In RT systems, however, cover crop residue remains on the soil surface after cover crop termination in order to suppress weed growth through chemical and physical means.

Allelopathy has been described as the plant production of biochemicals that can impede plant germination and growth in the absence of resource competition (Einhellig 1994). These biochemicals, or allelochemicals, are released from plants through volatilization, leaching, root exudation, and plant degradation during active growth as well as from plant residue (Weir et al. 2004). In this manner, cover crops provide weed suppression while growing and continue to provide a level of suppression after cover termination. A number of classes of allelochemicals, including phenolic acids, coumarins, and glucosinolates, have been identified in cover crop species (Vyvyan 2002). Although the specific means of plant inhibition for many allelochemicals are just beginning to be understood, the allelopathic weed potential of a number of cover crops is apparent in several studies (Burgos and Talbert 2000; Khanh et al. 2005; Norsworthy et al. 2005; Price et al. 2008; Walters and Young 2008).

In addition to allelopathy, cover crops can suppress weed seed germination and growth by plant residue modifications to the soil microenvironment (Masiunas et al. 1995). Cover crop residues on the soil surface can affect light availability, temperature, and moisture levels in the region of weed seed germination, reducing the number of germinating weed species (Creamer et al. 1996a). While plant residue remains on the soil surface, the physical interference of cover crops can continue to suppress weed species into the growing season. The high C : N ratio of cereal grains results in a slow degradation of cover crops, allowing for increased plant residue persistence over legume cover crops; brassica species tend to break down more rapidly than cereals but persist longer than legumes (SARE 2007). With increased weed control achieved with higher levels of plant residue, the use of cover crops adapted to specific environments can ensure adequate levels of biomass production for soil coverage and weed suppression in RT systems.

Brassica Cover Crops. A number of species in the Brassica family have been used as cover crops in several cropping systems, particularly vegetable and specialty crop production (SARE 2007). Brassica species such as wild radish, rapeseed (*Brassica napus* L.), black mustard (*Brassica nigra* L.), and white mustard (*Sinapis alba* L.) contain isothiocyanates (ITCs), derivatives of glucosinolates, that have noted pesticide properties including herbicidal activity (Norsworthy and Meehan 2005a; Malik et al. 2008). In addition to physical weed suppression from brassica covers, several species have shown the allelopathic effects of ITCs to inhibit germination of weed species such as redroot pigweed (*Amaranthus retroflexus* L.), dandelion (*Taraxacum officinale* Weber), yellow nutsedge (*Cyperus esculentus* L.), sicklepod (*Senna obtusifolia* L.), and Palmer amaranth [*Amaranthus palmeri* (S.) Wats.] (Norsworthy 2003; Norsworthy and Meehan 2005a,b,c). Currently, use of brassicas in vegetable productions primarily is limited to green manures with soil incorporation prior to cash crop planting. Incorporation of brassica residue allows for biofumigant allelopathic suppression of soilborne diseases, nematodes, and weed species (Larkin et al. 2012; SARE 2007).

Relatively little research has been conducted on the potential for brassica cover crops to suppress weeds in RT cropping systems. Although research with brassica species has resulted in variable outcomes for weed suppression and crop sensitivity (Lawley et al. 2012), efforts have continued to evaluate unincorporated brassica cover crops. One such study showed early-season weed suppression by unincorporated wild radish to be equal to that achieved with a rye cover crop (Malik et al. 2008). Researchers in the Southeast continue to explore the multiple uses of brassica cover crops in vegetable and row crop production. Future efforts to determine how weed suppression is affected when brassica species are used as a ground cover as opposed to incorporated into the soil are necessary to determine the most effective ways to utilize these cover crops in RT vegetable systems.

Cereal Grain Cover Crops. Annual cereal grains are frequently used as winter cover crops for their winter hardiness and biomass production and as a catch crop for soil nitrogen (SARE 2007). Species such as rye, wheat, and black oat (*Avena strigosa* Schreb.) are used throughout the Southeast, mainly in row crop production (Price et al. 2008). In addition to providing erosion control and scavenging N from the soil, grain cover crops can provide a level of weed control through both physical and allelopathic means. Rye, in particular, has been shown to be a hardy cover crop that can successfully compete with many weed species while actively growing. Benzoxazinoid compounds produced by some grains such as wheat and rye can exhibit allelopathic effects on various weed species (Macias et al. 2005). Cereal covers have been effective for inhibiting germination of weeds such as giant foxtail (*Setaria faberi* Herrm.), common lambsquarters (*Chenopodium album* L.), velvetleaf (*Abutilon theophrasti* Medik.), pigweed (*Amaranthus* spp.), horseweed [*Conyza canadensis* (L.) Cronq.], and barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] (Burgos and Talbert 1996; Przepiorkowski and Gorski 1994).

Research has evaluated weed suppression by cereal cover crops such as rye in RT row crops with positive results (Price et al. 2006; Reeves et al. 2005). However, limited research has been conducted with cereal covers in RT vegetable production systems, particularly in the Southeast. Mulvaney et al. (2011) did report reduced weed density after 3 yr of NT organic collard production including a high-residue rye cover crop. Continued efforts to identify improved practices for cover crop management and termination should help to increase the use of cereal grains as cover crop choices in vegetables.

Legume Cover Crops. A variety of legume cover crops are planted alone or in a mixture with grass covers to help reduce soil erosion, increase soil organic matter, and suppress weed species (SARE 2007). Additionally legume cover crops can fix nitrogen to be available for following cash crops. Species such as clover (*Trifolium* spp.), white lupin (*Lupinus albus* L.), Austrian winter pea [*Pisum sativum* L. ssp. *arvense* (L.) Poir.], and hairy vetch (*Vicia villosa* Roth) can function as cover crops in a number of crop production systems (Akemo et al. 2000; Daniel et al. 1999; Mohler and Teasdale 1993; Norsworthy et al. 2010). Allelopathy has been noted for some species such as cowpea, sunn hemp (*Crotalaria juncea* L.), and velvetbean [*Mucuna pruriens* (L.) DC.]; however, chemical weed suppression has not been identified for most legumes typically used as cover crops (Adler and Chase 2007; Mosjidis and Wehtje 2011; Price et al. 2008). Successful weed control achieved by legumes is primarily attributed to biomass production, which can shade germinating weeds; however, legume cover crops tend to have a low C : N ratio and decompose rather quickly compared to other cover crops, which can reduce their potential for weed control further into the growing season (SARE 2007).

A number of studies have examined legume cover crop use in RT with results indicating that these covers perform best in a mixture with a cereal grain rather than in a monoculture (Brennan et al. 2009; Reberg-Horton et al. 2012; Yenish et al.

Figure 1. Auburn University research plot evaluating a polyethylene/cover crop mulch integrated system pioneered by Mr. Bob Rollins, watermelon producer, Turner County, Georgia.

1996). Longer-term weed control may also be achieved when planting legumes in a mixture due to rapid decomposition of legume-only residue (Burgos and Talbert 1996). Research in RT tomato production outside the Southeast has reported high yields and successful weed control either alone or in mixture (Abdul-Baki et al. 1996; Creamer et al. 1996b). More recently, legume covers have been reported to provide early-season weed suppression but require subsequent herbicide applications to maintain season-long weed suppression in tomato (Saini et al. 2007).

Cover Crop Termination in Reduced-Tillage Systems. Regardless of the type of cover crop grown, management practices, particularly termination timing and method, are critical to ensuring that the cover crop functions as intended. Current recommendations for cover crop termination in vegetable production generally suggest plowing or disking of the cover crop (Anonymous 2012). In RT systems, however, cover crop biomass remains on the soil surface and timing of termination can affect multiple aspects of the cropping system such as water and nutrient availability and soil temperature. Implementing an earlier kill date for cover crops can reduce the loss of soil moisture and allow more rapid soil warming; a later kill date increases the amount of residue produced which can lead to enhanced weed suppression (Balkcom et al. 2007).

In addition to timing, mechanisms for terminating cover crops can vary depending on the type of cover crop. In general, cover crops grown for ground cover can be killed with herbicide applications, mowed, and/or rolled (Balkcom et al. 2007; Reberg-Horton et al. 2012). Rolling/crimping of cover crops has been the focus of recent research as a potential means of cover crop termination in low-input or organic systems; however, timing of rolling operations for effective termination without herbicides is species specific (Mirsky et al. 2009; Reberg-Horton et al. 2012). Cover crop regrowth during the primary crop growing season may be possible regardless of termination method and must be planned for in addition to the shift toward annual and perennial grasses typical of RT systems (Bàrberi 2002; Creamer and Dabney 2002; Mirsky et al. 2012).

Organic Vegetable Production. Despite environmental benefits that can be achieved through the use of organic practices, adopting organic systems in the Southeast can be challenging for several reasons. With little region-specific research or guidelines available to producers, implementing organic practices can be a costly trial-and-error undertaking; moreover, the warm, humid climate in the Southeast promotes high pest pressures in these organic systems that have limited control options (Mississippi State University 2011; Treadwell et al. 2007). As research continues, however, a number of fruit and vegetable crops, such as sweetpotato [*Ipomoea batatas* (L.) Lam.], onion (*Allium cepa* L.), lettuce (*Latuca sativa* L.), squash (*Cucurbita pepo* L.), collard (*Brassica oleracea* L.), and bell pepper (*Capsicum annuum* L.) (Chellemi and Rosskopf 2004; Evans et al. 2006; Mulvaney et al. 2011; Treadwell et al. 2008; Vollmer et al. 2010), have been grown successfully in organic production systems of the Southeast.

Adopting RT practices in organic systems pose further challenges from a weed management standpoint. Effective weed control can be difficult to implement when standard weed management practices in organic production rely primarily on tillage and hand removal to obtain successful levels of weed control (Creamer and Baldwin 2000; Norsworthy and Meehan 2005a; Treadwell et al. 2007). The need to identify and develop multiple, alternative control strategies for integrated weed management in organic vegetable production in the southeastern United States has been recognized and continues to generate research to assist producers in the transition from conventional systems (Smith et al. 2007; Treadwell et al. 2007). To that end, a number of practices have been examined for their potential use in organic systems as alternative weed control measures. Among these practices are the use of mulches, soil solarization, seeding rates, cover crops, and integrated tactics using multiple practices (Figure 1). Addition of these practices into weed management systems may allow for increased utilization of RT in organic productions.

Cover crops, in particular, can be an integral component of integrated weed management systems in RT organic systems. Many studies in the Southeast have evaluated the efficacy of cover crops for weed control in RT organic vegetable production with most, but not all, results showing positive weed suppression by cover crops compared to fallow or no-cover systems (Chellemi and Rosskopf 2004; Norsworthy et al. 2007; Treadwell et al. 2007; Wang et al. 2008). However, weed control provided by covers should not be relied on as the exclusive weed control strategy, but covers may provide a level of suppression for some weed species (Norsworthy et al. 2007). Although no one practice can provide adequate weed control in organic vegetable production, use of cover crops in conjunction with other cultural control methods may provide sufficient weed suppression without the need for intense tillage practices.

Summary and Conclusions

With weed competition as one of the most problematic issues in vegetable production, weed control is at the forefront of research needs. Continued research efforts to determine successful methods for implementing RT as well as cover crops as ground cover are necessary to provide alternative weed control strategies. Research is needed to identify appropriate high-residue cover crop choices and integrated weed management practice for use in vegetable cropping systems, whether organic or conventional, that offer adequate weed control without reducing crop yield. Specifically, cover crop choice, planting, and termination guidelines for diverse cropping systems are needed that maximize cover biomass and subsequent weed suppression. In addition, weed management and cover crop termination during crop rotation transition continues to challenge RT organic producers. Ultimately, these types of research will help shape the future of more productive and sustainable vegetable systems across the Southeast.

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