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Title: Cereal Residue Effects on Weeds and Cucumbers

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Cereal residues suppress the development of small seeded, summer annual weeds. The focus of this study was to determine whether cereal residues can be used to suppress weeds in cucumber production systems in the Pacific Northwest. In the first of three experiments, cereal residues of fall-planted, spring-killed cover crops suppressed weed density and dry matter by 65 and 34 percent respectively, compared to treatments with no residue at 6 weeks after cucumber planting. But this level of weed suppression was not an advantage compared to conventional tillage and cultivation. In another scenario, glyphosate was applied over the cereal residues post-plant but before cucumber emergence. Weed density was unaffected but weed dry matter was dramatically reduced. Several residue treatments reduced weed dry matter to a level comparable to the cultivated, conventional tillage control. Weed suppression at the end of the harvest season was unacceptable in all residue treatments, however. Cucumber yield was severely reduced in residue treatments due to weed competition.

A second experiment quantified the effect of cereal residues on cucumber growth in no-till conditions and the mechanisms affecting cucumber growth. An inert mulch of *Populous excelsior* wood shavings significantly increased cucumber growth compared to a natural barley residue even though soil temperatures were

equal. Tillage improved plant growth but activated charcoal and metalaxyl treated seeds did not affect growth in no-till conditions.

A third experiment examined the weed suppression of a stale seedbed system that included barley and rye planted 0, 2, and 4 weeks before cucumber seeding. Barley and rye improved weed suppression by 85 percent compared to the same treatments without cereals. Cucumber yield of all treatments was less than the weed-free control, but comparable with average yields of commercial cucumber production.

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CHAPTER 1

INTRODUCTION

Excessive tillage in vegetable production systems increases soil erosion, compacts the soil, promotes soil organic matter loss, and consumes excessive fossil fuel (Stinner and House, 1990). Minimum tillage systems have evolved to address these concerns, but weed control strategies must be changed. In many instances, herbicides become the favored tool (Barnes and Putnam, 1983). Another option manipulates residues or mulches from previous crops or cereal cover crops to suppress weeds.

Cereal cover crops reduce erosion, recycle nutrients, improve soil structure, and increase soil organic matter (Worsham, 1991). If the cover crop is used as a mulch rather than turned into the soil, other positive benefits accrue. These include weed suppression, reduced soil water loss, improved soil structure, and less soil loss (Worsham, 1991). However, cereal mulches also interfere with cultural practices, reduce soil temperatures in the spring, and aggravate certain pest problems (Weston, 1990). The later two are of particular prominence in the maritime climate in the Willamette Valley of Oregon (Petersen et al, 1986). Another major problem is the lack of equipment that effectively direct-seeds vegetable crops through cereal mulches, although the problem is ameliorated somewhat by transplanting.

The practical application of cereal mulches to suppress weeds has many variations, but is best illustrated by two examples (Worsham, 1989). Most common is the minimum tillage/cover crop systems with fall-planted cereals that are winter killed or destroyed with herbicide in the spring (Barnes and Putnam, 1983). Cereal crops are desiccated near booting stage when mulch biomass potential is near maximum. A second system uses cereals that are sown in the spring, 3 to 6 weeks ahead of the crop, then desiccated with herbicide shortly before or after crop seeding to provide a surface residue (Putnam and Duke, 1983). This system has been adapted to cucumber production in Michigan to avoid wind injury to cucumber seedlings on very light soils, with the added benefit of weed control (Dudek et al, 1991).

These two cereal systems differ in three important respects. First, tillage is limited in fall-planted systems. The absence of cultivation may be responsible for 50 percent of the weed suppression; incorporating the mulch provides very little suppression (Worsham, 1991). In contrast, tillage is included in the spring system before establishing the cereal crop, although this still represents a limited-tillage condition. Second, fall-planted cereals are desiccated with herbicide (if not winter-killed), usually near boot stage, providing a dense mulch. The spring-planted system may include cereals that only have grown to 12 inches. Third, in the fall-planted scenario, minimal herbicide reaches the soil and accounts for very little of the weed suppression in the system. In contrast, in the spring planted system herbicide activity may be the predominate factor if cereal growth is minimal.

The objective of this thesis is to evaluate the potential of employing cereal residues as a weed control strategy for commercial cucumber production in the Willamette Valley of Oregon. General areas of investigation included 1) the extent and nature of weed suppression with cereal mulches in fall-planted, no-till and spring-planted vegetable production systems, 2) the effect of cereal residues on cucumbers, 3) and the underlying mechanisms that effect cucumber growth in minimum-tillage conditions.

Complicit in any inquiry is a governing methodology, whether stated or assumed. Many have challenged the reductionist approach of science that assumes reality is best understood by scrutinizing the individual parts of a system. The focus on dividable parts has produced research agendas that are poorly linked to practical problems (Vietor, 1992). Additionally, by focusing on small segments of large problems, science has failed to address the larger problems that face humankind (Bawden, 1991).

In this context, agricultural research is undergoing a transformation and adapting to a new paradigm. Bawden (1991) asserts that "we need to address critically the need for a new science that embraces both production enhancement and impact assessment while transcending both" of these goals. Development of models or methodologies such as Farmer Back to Farmer (Rhoades, 1982), Farmer First (Chambers et al, 1989), Participatory Research (Francis et al, 1990), and Systems Inquiry (Bawden, 1991) illustrate this transformation. Bawden and Macadam (1988) advance that a move toward a systems perspective in research is essential to meet future challenges. They propose that a hierarchical model of complementary yet nested methodologies be implemented for problem solving and development of appropriate research agendas. These nested methodologies range from the broad perspective of human activity systems research to the very concentrated focus of basic research. The choice of methodologies is contingent on the situation and the level of complexity within the problem.

The methodology pursued in this thesis was constructed on these premises. First, an attempt was made to define the inquiry from a broad perspective through individual interviews with farmers, a focus group session, and presentation of results at growers meetings to solicit feedback on methodology and results. Second, a research agenda was developed that addressed concerns from both an applied and basic research perspective.

The stage for this thesis was set in December of 1990 at a focus session for cucurbit producers. Growers identified two primary areas of research focus on weed control from several alternatives: use of activated charcoal as an herbicide protectant; and use of 'allelopathic' cereal residues for weed suppression. Individual interviews were conducted during the summer of 1991 with four cucumber growers to gather information on typical approaches and constraints to cucumber production including weed control practices, and what the growers envisioned as an improvement over current practices. In March of 1992, another focus session was organized to directly address the issue of weed control in cucumbers. Participants included growers, processing representatives, and university extension personnel. The objective was to listen to growers' concerns and build on the synergism generated by those of various experience and knowledge. Research with activated charcoal and herbicides is not presented here but was conducted concurrently. The methodology employed fostered a level of understanding that definitely shaped the development of this thesis.

CHAPTER 2

REVIEW OF LITERATURE

CEREAL RESIDUE EFFECTS ON WEEDS

Extent and Nature of Weed Suppression. Cereal mulches suppress the accumulation of weed biomass and reduce weed density in the early season (Putnam and Defrank, 1983; Teasdale, et al 1991). For example, Worsham (1991) reported that a desiccated small grain cover crop plus a no-till seed bed provided nearly 80 percent early season control of a number of annual broadleaf weeds. However, weed control was much less later in the season. In a perennial crop of strawberries, cover crops desiccated with fluazifop-butyl significantly reduced weed biomass by 80 to 95 percent compared to the control (unmulched, unweeded plot) in the early season but by only 55 percent by mid-season (Smeda and Putnam, 1988). In a system with several vegetable crops, early season weed biomass was reduced by 75 percent with a desiccated fall-planted, cereal cover crop; after 60 days, weed biomass in the mulched plot was 63 percent of a conventionally tilled and unweeded plot (Barnes and Putnam, 1983; Putnam and De Frank, 1983).

These examples demonstrate the diminishing weed suppression of cereal residues as the time from mulch establishment lengthens. Others have documented mulch impacts on weeds at the end of the crop season. Teasdale (1991) reported that rye (*Secale cereale L.*) residues reduced weed density at corn harvesting in no-till sweet corn production compared with no-till, unmulched plots in only two of four years. Additionally, a rye mulch with no-till resulted in a slight increase in control of late-season lambsquarter and other weeds when compared to no-tillage in tobacco production. However, the mulch did not reduce weed density or biomass to an acceptable level at tobacco harvest, or a level that did not significantly interfere with the tobacco crop (Shilling et al, 1986).

To compensate for this declining influence of the mulch on weed populations, other weed control tactics are needed to shift the balance from short-term weed suppression to long-term weed control. Several systems were tested that combine a cereal mulch with other tactics such as tillage or herbicides. For instance, Mohler (1991) demonstrated that weed biomass at season's end was lower in rye mulch plots than in the corresponding unmulched plots in a no-till sweet corn system with the herbicides atrazine and metolachlor. In North Carolina, a rye mulch coupled with the use of diphenamid resulted in a 17 percent increase in early season weed control in tobacco, but weed control still was not an improvement over conventional management (conventional seedbed preparation, one application of the herbicide diphenamid, and two cultivations) at tobacco harvest. Others have documented the interactions of herbicide and mulch. One researcher found that metolachlor applied over a straw mulch was as effective as twice the rate of metolachlor applied to a no-till soil surface. The mulch may have weakened seedlings so that the herbicide was more effective (Crutchfield et al, 1985).

Interpretation of the forementioned research is confounded by the comparisons used to evaluate mulch effects. In some cases, performance was evaluated against unweeded checks rather than a standard such as a currently accepted system. This exaggerates performance from a practical perspective. For example, Putnam and Defrank (1983) reported that early season weed biomass was reduced by 75 percent with a desiccated fall-planted, cereal cover crop compared to a conventionally tilled and unweeded plot. While this demonstrates the mulch effect, it does not quantify the appropriateness of a technology compared to standard or generally accepted practices. A preferable evaluation compares conventional or standard practices with the use of cereal residue systems.

Cereal mulches affect weeds at three distinct stages in seedling and plant development: germination, from growth to emergence through the mulch, and growth after emergence. Putnam and Barnes (1983) concluded from a laboratory study that mulch effects on early seedling growth were more important than the effect on germination. Mohler and Calloway (1992) concurred as they found that emergence for most weed species was significantly reduced in a rye mulch. Evidence indicated that fewer emerged weeds and lower weed biomass were probably due to effects on plant growth (ie. radical elongation and shoot growth) rather than germination. They also found that rye mulch had no effect on survival of weeds that emerged, thus pointing to the intermediate stage as the most critical. This evidence diminishes the importance of light and temperature factors in the reduced emergence of weeds found in mulched soils.

Weed species differ in sensitivity to cereal residues. In general, summer annuals are most affected. Emergence of *Portulaca oleracea* was particularly sensitive to a rye mulch while the emergence of *Chenopodium album* and *Digitaria sanguinalis* also were reduced but to a lesser extent (Mohler and Calloway, 1992). Putnam and De Frank (1983) noted that residues of small grains were particularly inhibitory to the summer annuals of *Chenopodium album L.*, *Portulaca oleracea L.*, and *Amaranthus retroflexus L.* This apparent selectivity also was noted in the response of wild oat (*Avena fatua L.*) and cultivated oat (*Avena sativa*) to the same mulch (Perez, 1990). Additionally, large seeded weeds are less affected than small seeded weeds (Triplett and Lyttle, 1972; Worsham, 1988). No-till systems in general increase monocot populations relative to dicots, primarily Graminaceae (Putnam et al, 1983; Wrucke and Arnold, 1985).

Factors Affecting Weed Suppression. General observations indicate that weed suppression is related to density or biomass of the mulch (Almedia, 1985; Teasdale and Mohler, 1991; Teasdale et al, 1991; Mohler and Teasdale, 1992). For instance, rye residue from a fall-planted cover crop caused a 22 and 29 percent decrease in broadleaf and grass weed density, respectively, compared to a no-till, unmulched plot. Rye also suppressed weeds more effectively than wheat (*Triticum aestivum L.*), barley (*Hordeum vulgare L.*) or oats (Shilling et al, 1986). Shilling surmised that the difference in weed suppression was due to either allelopathic properties or simply the fact that rye accumulated more biomass in this study than wheat or barley; wheat and barley did not over-winter well and contributed less residue in the spring.

Of a more concrete nature, Teasdale and Mohler (1991) found a significant correlation (r^2=0.75) between cover crop biomass at the beginning of the year and weed density reduction one month later. Though weed suppression was correlated with biomass, even very high rates of residue did not preclude weed emergence; residues of 2 to 4 times the natural rate, (2.8 to 5.6 t ha^{-1}, respectively) still allowed some weeds to establish.

Although biomass accumulation indicates weed suppression potential, percent soil surface coverage by the residue may be more reliable. A model developed for weed suppression by cereal mulches predicted that weed density would be unaffected unless soil coverage reached 42 percent, and that 97 percent coverage by the residue was required to reduce weed density by 75 percent. This model was confirmed by field results in which weed density reduction was significantly correlated with percent residue cover (r^2=.91) (Teasdale et al, 1991).

Observations in plant community ecology indicate that type of surface residue affects community evolution (Facelli and Pickett, 1990). Cereal mulches contain differing proportions of compounds that are biologically active, and these compounds may affect various weed species differently (Chase et al, 1991). Other varietal or species characteristics such as color also may be important. Rye mulches killed by paraquat are light colored, therefore reflecting more light than dark colored leguminous mulches. As a consequence leguminous mulches have a higher surface temperature; colder soil temperatures may shift the species emergence pattern, slow the growth of weed species, or enhance growth of cool season species (Mitchell and Teel, 1977).

The herbicide or method used to kill the cover crop interacts with the cereal residue to determine the weed suppression of a cereal residue system. In one report, differences in weed suppression were noted due to method of cereal desiccation, but were not limited to the effect of the herbicide. Weed suppression of rye increased according to the following order: rye treated with fluazifop butyl and mowed, rye treated with paraquat, rye treated with glyphosate, and rye treated with fluazifop butly but not mowed (Smeda and Putnam, pers com.). The effect of the herbicide may be a confounding factor, particularly if herbicides with differing weed control spectrums such as glyphosate and fluazifop-butyl are applied.

The maturity of a cereal mulch influences weed suppression of the residue, and maturity depends on the growth stage at desiccation. Immature cereals restricted growth of summer annuals such as *Portulaca oleracea L.* and *Amaranthus retroflexus L.* more than mature cereals (Putnam and Defrank 1983). In a greenhouse study, reduced emergence of both lettuce (*Lactuca sativa*) and yellow foxtail (*Setaria lutescens*) increased in a linear fashion as the age of the rye (*Secale cereale L.*, 'Wheeler') at time of kill increased from 20 to 50 days (Barnes and Putnam, 1983).

Essential to effective weed control with mulches is minimum soil disturbance. In a no-till system with cereal residue, Shilling (1989) found that the no-till environment is responsible for as much as 40 to 50 percent of the weed suppression of a cereal mulch system. The highest degree of weed suppression was achieved with mulch plus no-till under several different regimes. Therefore, soil disturbance that occurs during crop seeding or other cultural operations will impact mulch effectiveness.

In a field trial with tobacco, side-dressing fertilizer and applying fertilizer during the transplanting operation with a disk and shank significantly stimulated weed emergence where the mulch and soil were disturbed (Shilling et al, 1986). A modified transplanter and banding of the fertilizer on the soil surface greatly reduced weed growth. Disturbance related weed emergence is apparently due to changes in the light environment. Wesson and Waring (1968) found that in many species only a brief moment of light exposure is needed to induce germination. Soil disturbance also improves soil-to-seed contact and moisture uptake of weed seeds, and hence emergence (Wesson and Waring, 1968). In particular, emergence and establishment of large-seeded species is improved by shallow incorporation (Froud and Williams, 1984).

If mulches are to be effectively employed, the full cropping system must be considered over a period of several years. Weed control with a mulch system may differ markedly in the second year if weeds are allowed to produce seed and the weed seed bank increases. In minimum tillage systems, weed seeds remain on the soil surface. This may be advantageous in some situations because the seeds are exposed to less favorable conditions. However, weed densities in a no-till, cereal mulch experiment significantly increased from one year to another in an experiment where weeds were allowed to produce seeds. This was expected because weed seeds remained on the surface under continual no-till cultivation (Teasdale, 1991).

The competitive ability of a crop interacts with the mulch to affect weed suppression. Weed biomass was significantly greater in the noncropped, mulched controls compared to mulched plots with sweet corn in all years except one in a four year study (Mohler, 1991). Additional competition from the crop significantly decreased weed biomass. Without competition from sweet corn, weed seed production increased dramatically, and the increasing weed density over the course of the four years had a dramatic impact on weed populations in the no-till control. No-till treatments with cereal residue that were moderately successful were complete failures without the crop, indicating that the competition afforded by corn rendered an important role in long term weed control (Mohler, 1991).

Mechanisms of Weed Suppression. Important mechanisms affecting seed or seedlings under cereal residues include light quality and quantity reaching the seed, soil temperature, and allelopathy.

Light. Both light quantity and light quality reaching the seed or emerging seedling are factors which are influenced by a surface mulch. Weed seeds under a mulch are subjected to a lower intensity of light and therefore, less light in the far red range. The majority of weed species depend on 1 to 1000 umol m^{-2} of red light to germinate (Kronenberg, 1986). However, Teasdale and Mohler (1992) demonstrated that the light requirement at the soil surface needed to germinate seeds is satisfied within seconds to minutes under a cover crop residue level of up to four times the natural rate, or 3.8 t ha^{-1} of dead hairy vetch (*Vicia villosa* Roth) or rye. The mean photosynthetic photon flux density (PPFD) was not reduced to less than 1 percent of unobstructed light at the surface level.

Two factors modify this observation. First, many weed seeds are partially buried. And secondly, light penetration into soil can induce germination of light sensitive seeds located up to 2 mm beneath the soil surface (Wolley and Stoller, 1978). Therefore, the reduction in light intensity due to additional residue on the soil surface may be sufficient to cause a reduction in weed germination and emergence, even though light intensity at the soil surface is adequate to cause germination under high levels of residue (Teasdale and Mohler, 1992).

The quality of light reaching the soil surface is altered by cereal residues. Chlorophyll of green plant tissue absorbs the red light wavelengths of light, decreasing the red-to-farred ratio of light striking the seed and causing the phytochrome pigments of the seed to convert to the inactive form. This effect keeps light sensitive seeds dormant in shaded conditions (Harper, 1972). However, Teasdale and Mohler (1992) found that rye residue had little effect on light quality compared to unobstructed sunlight even though light intensity under the residue was greatly reduced. Chlorophyll begins to degenerate after cereal desiccation until it is nearly completely lost at crop seeding. The researchers concluded that the slight change in light quality due to the rye residue was insufficient to account for reduced emergence of weed seedlings. But two factors challenge their conclusion: green cereal tissue slowly losses its chlorophyll after desiccation and could influence seed germination for two to three weeks before the crop is actually planted; and most weed seeds are partially buried which may affect the ratio of R:FR light that the weed seed receives.

Cereal mulches present a barrier to emerging seedlings, requiring additional time for the seedling to emerge into unobstructed light. A thick mulch increases the distance that the plant must grow and the time it depends on stored food reserves. If seedlings do not receive enough light before emerging from the mulch, they exhaust food reserves and die (Teasdale and Mohler, 1992). Increased time within the mulch may increase the risk of death by predation or disease, although this is undocumented. The light required for weed seedlings to grow is available under many natural cover crop residues, suggesting that reduced emergence is related to other factors (Smith, 1986). However, the barrier effect is strictly dependent on mulch density, percent soil-coverage provided by the mulch, and carbohydrate reserves of the seedling. Large seeded or perennial weeds with carbohydrate reserves in roots are favored (Teasdale and Mohler, 1992).

Soil Temperature. Many weed seeds require a specific temperature or range of temperatures before they will break innate or secondary dormancy and germinate. Crop seeds are generally immune to this effect. For instance, many summer annuals require a high temperature to induce germination (Baskin and Baskin, 1985). A general rule is that a fluctuation of 10 C is needed to stimulate germination of weed seeds that exhibit a response to diurnal fluctuations (Teasdale and Mohler, 1992).

Cereal residues ameliorate diurnal fluctuations in the upper soil layers and reduce average soil temperature, a result of less solar radiation and light reaching the soil surface (Teasdale and Mohler, 1992). Therefore, reduced weed seedling emergence under a mulch may be due to lower soil temperatures or air temperatures within the mulch that slow seedling growth, and smaller diurnal fluctuations in soil temperature that keep weed seeds dormant. In contrast to the lower temperatures in and under a mulch, surface temperatures of mulches are consistently higher than bare soils and may actually kill or damage seedlings as they emerge through the mulch (Mitchell and Teel, 1977). Teasdale and Mohler (1992) propose, however, that lower soil temperatures under a mulch are insufficient to fully prevent germination of seeds, although reduced germination and delayed emergence might be expected.

Allelopathy. Allelopathy is the negative effect of one plant on another through release of compounds with biological activity (Rice, 1974). Cereal residues effect the chemical environment of the weed seed under a mulch through allelopathic toxins which are leached, volatilized from the crop, or microbially modified and contact the weed or crop seed or seedling.

Several controlled environment studies have demonstrated that a variety of biologically active and possibly allelopathic compounds are present in cereals (Willard and Penner, 1976; Barnes et al, 1987; Wojcik-wojtkowiak, 1990; Chase et al, 1991;). Early work by researchers indicated allelopathic action in barley (Went et al, 1954). In fact, most crop residues contain water soluble chemicals that can depress the growth of plants (Guenzi and McCalla, 1962). Allelopathic agents of cereals include phenolic acids, aliphatic acids, aldehydes, ketones, benzoic acids, terpenoids, coumarins, and flavinoids (Robinson, 1980; Whittaker, 1970).

Hydroxamic acids are the primary class of compounds isolated from rye as allelopathic agents. Hydroxamic acids also are implicated as agents in plant resistance to diseases (Niemeyer, 1988). Two important hydroxamic acids isolated from rye and other cereals are BOA (2(3)H-benzoxazoline) and DIBOA (2,4-dihydroxy-1,4(2H)-benzoxazin-3-one) (Barnes et al, 1987). These two complex hydroxamic acids occur in intact plants as glycosides and convert to BOA and DIBOA when extracted from the plant (Willard and Penner, 1976).

Corn (*Zea mays*) and wheat (*triticum durum*) contain higher concentrations of DIMBOA (2,4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one) than DIBOA (Zuniga et al, 1983; Barnes et al, 1987). *Hordeum spp* and a sorghum hybrid (*Sorghum sudanense X S. vulgare*) contain neither DIBOA or DIMBOA (Zuniga, et al, 1983). In fact, hydroxamic acids have not been found in members of the genera *Avena, Hordeum, or Oryiza* (Niemeyer, 1988). Barley (*Hordeum vulgare*), however, is one of the more highly regarded smother crops and is commonly used to suppress weeds. Overland (1966) demonstrated through growth, germination and leachate experiments that the superior weed suppression of barley was due to more than competition, but she did not implicate specific compounds as allelopathic agents. She also demonstrated that weed suppression with barley is selective.

Microbial breakdown products of compounds isolated from cereals may be allelopathic agents, and even subject to biomagnification in the soil environment (Chase et al, 1991; Guenzi and McCalla, 1966). Of the many types of phytotoxic compounds released from decaying plant material by microbial activity or leaching, the phenolic acids are probably the most common (Rice, 1974; Whittaker, 1970). In rye, BOA and DIBOA are rapidly converted to 2,2'-oxo-1,1'azobenzene (AZOB) via *Acinetobacter calcoaceticus*, a bacteria isolated from field soils that was found to be responsible for the biotransformation of BOA to AZOB (Chase et al, 'III' 1991). AZOB is generally more active on seedling growth than BOA.

Many compounds isolated from cereals have been implicated as agents of allelopathy. However, it is difficult to demonstrate conclusively that weed suppression in field studies is due to allelopathy. Fuerst and Putnam (1983) suggest a four step model to verify that the mode of action is actually allelopathy. First, the symptoms of interference must be identified. Second, isolation, characterization, and synthesis of the toxin is required. Third, the interference noted under field conditions must be duplicated by supplying the toxin in purified quantities in amounts that are found in nature. And last, quantification of the release, movement and uptake of the toxin is required. While this model may have validity under some conditions, in reality there may be many compounds interacting at any one time, with variable proportions.

The following references are good examples of the diversity of opinion and difficulty associated in linking allelopathy to weed suppression. Weed densities under two fall-planted, spring-killed rye varieties in a no-till pea planting were nearly the same as under a similar residue of non-toxic mulch of *Populous excelsior* wood shavings (PE). However, weed biomass was significantly lower in the rye mulches compared to the PE mulch. Preliminary tests using a LI-COR sensor quantum/radiometer/photometer indicated that equal weights of PE and rye residue contributed the same amount of light and soil temperature reduction. Greenhouse experiments indicated that PE had no toxic effects while rye extracts reduced germination and shoot and root growth in some species. The conclusion: allelopathy is an important component of weed suppression (Barnes and Putnam, 1983).

From another point of inference, Teasdale and Mohler (1992) compared weed suppression of hairy vetch (*Vicia villosa* Roth) and rye (*Secale cereale* L.). From measurements of light intensity and light quality taken under the mulches, they concluded that differences in weed seedling germination and emergence between the two species was not due to light effects. However, they found a very close correlation between percent soil coverage by the mulch or residue and weed density reduction. They surmised that the amount of biomass on the soil surface and soil coverage by the mulch was the controlling factor in weed suppression and that variety of mulch had little impact. This does not preclude allelopathic effects but it does clarify the relative impact. It is possible that allelopathic constituents of legumes such as hairy vetch were present (Ells and McSay, 1991) even though it is generally accepted that rye is potentially more allelopathic of the two species (Teasdale and Mohler, 1992).

If the allelopathic potential of cereals is to be exploited to its full potential, differential responses by weed and crop seeds or seedlings is essential. Chase and company (1991) noted from a petri dish analysis that plant produced hydroxamic acids were more inhibitory to cucumber and snap beans than garden cress (*Lepidum sativum L.*) and barnyardgrass (*Echinochloa crus-galli*). Also, AZOB (the microbial breakdown product of BOA), strongly inhibited growth of several small-seeded weed species (Chase et al, 1991). Interestingly, seed germination of wild oat (*Avena fatua* L.) and cultivated oat (*Avena sativa*) was affected differentially when treated with extracts of wheat containing hydroxamic acids

(Perez, 1990). DIMBOA extracted from wheat inhibited root growth and seed germination of *A. fatua*, and MBOA at low concentrations stimulated root growth of *A. sativa*.

Moisture. Cereal mulches reduce drying of the soil surface, possibly establishing favorable conditions for germination of weed seeds, particularly summer annuals germinating late in the season (Teasdale and Mohler, 1992). In the early season, however, higher moisture may reduce the rate of soil warming, keeping seeds dormant longer, reducing seedling growth after germination, or reducing viable seeds through increased disease incidence (Staniforth and Wiese, 1985). These responses are totally dependent on weed seed species present, temperature, rainfall or irrigation patterns, and a host of other factors. The complexity of the interactions limits generalizations. For instance, in a conventional-tillage system, soil moisture had a greater effect on percent emergence of round leaved mallow (*Malva pusilla* L.) than soil temperature. In contrast, rate of emergence was affected more by soil temperature than soil moisture; a decrease in temperature increased the time of emergence compared to the warmer temperatures (Blackshaw, 1990).

Weed seed predation. Seed predation is an important force in plant population dynamics and may be important in agroecosystems (Harper, 1972). Plowing and cultivating the soil destroys habitat for many insects, beneficial or otherwise. Conversely, minimum tillage systems establish suitable habitats and encourage populations of soil inhabiting macroarthropods, especially ground beetles (Carabidae) and spiders, some of which are seed predators. Greater residue levels facilitate additional protection for these arthropods (Stinner and House, 1990).

Brust and House (1988) found that approximately 2.3 times more weed seeds overall and 1.4 times more large weed seeds were consumed in no-till systems than tilled systems. Large ground beetles (Carabidae: Coleoptera) and mice preferentially fed on the larger seeded species while small carabids, ants and crickets fed on smaller seeds. Carabid beetles were responsible for more than half of all seeds consumed. Also, litter-inhabiting arthropods such as Carabidae increase with decreasing tillage (House and All, 1981). These two factors may significantly impact weed populations over several years.

Disease. Fungal and bacterial propagule densities increase with decreasing tillage (Barber and Standall, 1977) and actually may be the reason for many reported cases of allelopathic affects on crops (Cook and Hoagland, 1991). However, the focus has been on disease impacts on crop plants rather than weeds; a primary concern of conservation or minimum tillage is the increased incidence of seedling diseases (Sumner et al, 1986). Similar responses might be expected of weeds although there is little evidence to document this theory. Coupled with increased surface moisture, disease incidence may influence weed seed germination and emergence.

CEREAL MULCH EFFECTS ON CROPS

Cereal residues potentially improve the growth of crops in addition to suppressing weeds. Production of transplanted tomatoes in Michigan on a sandy loam soil was feasible under no-till conditions with and without cereal residues. Yield of ripe or rotted fruit and yield per hectare were unaffected by tillage system. Soil temperatures for the three tillage systems (conventional, rye no-till and wheat no-till) were similar and did not appear to influence plant growth or yield. However, soil moisture was higher in conventional till than wheat or rye no-till, possibly due to the excessive growth of the cereals just before they were killed (Drost and Price, 1991).

Cucumber (*Cucumis sativus* L.), snap beans (*Phaseolus vulgaris* L.), and peas (*Pisum sativum* L.) were unaffected by cereal residues when sown 3 cm deep under desiccated immature spring cereals of barley, corn, oats, rye, sorghum (*Sorghum bicolor* L.), sudangrass (*Sorghum arundinaceum* (Desv.) Stapf. var sudanense (Stapf.) Hitchc.), and wheat. However, growth and development of smaller seeded vegetables such as tomato and lettuce were affected, possibly a factor of allelopathy, crop placement next to the residue, or seed to soil contact. Lettuce was nearly eliminated (Putnam and DeFrank, 1983). The difference in activity on weed and crop may simply be due to the position of the seed, as large seeded crops are sown deeper than crops such as lettuce or tomato. However, work by Dias (1991) suggested that seeding depth is not a factor in the response of crop seeds to cereal residues.

Factors Affecting Crop Growth. Cereal residues affect crops directly through possible allelopathic interactions or indirectly by modifying the microenvironment of the crop seed. These effects may positively or negatively affect crop growth and yield. The major factors negatively affecting crops include difficulties in crop seed placement through a residue, reduced soil temperature, and increased disease incidence, whereas increased soil moisture retention is often cited as a benefit to crop growth.

Crop seed placement. An obvious constraint encountered with no-till residue systems is the difficulty establishing good crop seed-to-soil contact, particularly for small seeded crops. Both crop and weed seeds respond well to finely tilled soils that maximize seed to soil contact (Staniforth and Wiese, 1985; Weston, 1990). Workers in Tennessee noted that as residue biomass increased, uniformity of crop establishment decreased, possibly due to the inefficiency of the planter in establishing good seed-to-soil contact (Weston, 1990). There also was a differential response among crops; cucumber emergence was greatest while snap bean emergence was significantly reduced. In another study, heavy growth of a rye cover crop and resulting residue was associated with irregular and low corn seedling density, and was due to the inefficiency of the no-till planter which tended to force rye residue into the soil opening rather than shear it off (Mitchell and Teel, 1977).

The factors limiting crop establishment and performance cannot be fully linked to the difficulty in establishing good seed-to-soil contact. Mohler (1990) noted that the initial variability of a stand can be overcome by overseeding followed by thinning of weak or late emerging seedlings. This observation suggests that the effect of residues is limited to the emergence stage. Even in situations where seed to soil contact is good (ie. hand planting to reduce cereal residue-to-seed contact), stand establishment may be inadequate. Reduced soil temperatures, disease incidence, and allelopathy are other factors implicated in crop establishment problems.

Soil temperature. Cereal residues reduce mean soil surface temperatures in the zone where seeds germinate and begin to grow (Mohler, 1992). In the tropics this may be an advantage (Okugis and Ossom, 1988), whereas in northerly locations this may be a serious detriment (Petersen et al, 1986) depending on the crop and extent of soil temperature reduction. Reduced soil temperatures will slow germination and emergence while lower air temperatures within the mulch reduce the rate of cell division in the apical meristem (Fortin and Pierce, 1991). In a controlled environment study, cucumber, pepper, eggplant, and tomato growth was severely retarded when soil temperatures dropped only 2.2 degrees C, from 14.5 to 12.3. Seedling root growth varied little between these two temperature regimes. Additions of phosphorus compensated somewhat for the decrease in top growth of cucumbers at the lower soil temperatures (Wilcox and Pfeiffer, 1990).

In the Pacific Northwest, sweet corn yield was reduced by 31 percent in no-till, flailed cereal plots compared to conventionally managed plots, and 16 percent compared to strip tillage (Petersen et al, 1984). The researchers attributed the yield decrease to lower soil temperatures, but suggested that the ineffectiveness of the planter at placing seed in the no-till plots, increased slug damage, and wet soils also were factors.

Disease incidence. Increased incidence of soil-borne root and foliar diseases is a primary concern in any system that does not include tillage (Sumner et al, 1986). Deep plowing is effective in reducing populations of pathogens such as *Rhizoctonia solani* that colonize plant debris, and *Sclerotium rolfsii*. Disease caused by *Pythium* spp, *Fusarium* spp, and *Verticillium* spp are generally unaffected by plowing or cultivation. Surface tillage or no-till keeps propagules and colonized plant debris near the surface and leads to higher rates of infection early in the season when the vegetable seedlings are most sensitive (Sumner et al, 1986). Sumner points out however, that the effect of these diseases dissipates markedly if unrelated crops are included in cropping rotations. In one example in continuous no-till wheat, poor emergence and growth was directly linked to disease; a break in the rotation quickly alleviated the problem (Cook and Hoagland, 1990). Crop rotations with unrelated crops are extremely important in reducing disease in no-till systems (Sumner et al, 1986).

While no-till or conservation tillage may increase disease incidence in specific situations, there is some evidence that cereal residues in no-till systems also may suppress growth and development of disease organisms, depending on pathogen, host, environment, and cereal residue (Watson and Cook, 1969). In one example, stem and stolon damage to potatoes caused by *Rhizoctonia solani* decreased when cereal residue was disced into the soil surface rather than fully incorporated (Gudmested, 1978). Mechanisms include antifungal exudates of shoots or roots that have direct effects on the disease organism, and increased microbial activity in the soil which produces fungitoxic substances (Lewis and Papvizas, 1975).

Allelopathy. Mulches may reduce yields of crops through allelopathy, but this connection is tenuous and easily confused with other factors such as disease incidence (Cook and Hoagland, 1991; Sumner et al, 1986). In one example, field corn yielded consistently lower under a rye cover crop whether the field was no-tilled, disced, or plowed. Yield was reduced whether the mulch was removed or maintained. However, tillage of plots with a cereal mulch and plots with the mulch removed reduced the effect of the cover crop. The authors speculated that the negative effect of the cereal probably resulted from allopathic compounds secreted before the crop was cut. They reasoned that tillage diluted the allelotoxins in the soil which accumulated from root exudates or the shoots of the cereal. Other factors such as soil temperature, N immobilization, or soil moisture were discounted because the removal or retention of rye residue had no significant effect on corn leaf area index, silking date, yield, and moisture content of the corn grain at harvest. Effects of soil structure and weed competition also were rejected as factors (Raimboult et al, 1990).

Other factors. Cereal mulches may also affect insect populations throughout the growing season and hence crop performance, both positively and negatively. Most of the evidence is derived from field crop studies, however. In soybean, seedcorn maggot (Diptera:Anthonyiidae) was unaffected by a surface residue of paraquat-desiccated rye or bare, tilled soil. When rye was tilled into the soil surface, seed corn maggot populations increased dramatically, reducing soybean emergence. Rotting rye in the soil apparently was beneficial to the maggot (Hammond, 1984)

The use of various mulches to reduce aphid populations in vegetable production has received considerable attention (Kring, 1972). Aphids are repelled by light colored surface mulches which reflect more shorter wavelength light than bare ground or tilled surface. Burton (1987) demonstrated that aphid colonization on grain sorghum was curtailed by the presence of surface residue, reducing the need for insecticides. Reflective mulches such as tin foil have been used in vegetable production to reduce aphid populations, thus increasing yield by delaying onset of diseases that aphids transmit (Kring, 1972; Conway et al., 1989).

Another factor that may affect crop growth is related to the method used to kill the cereal. For instance, in transplanted tobacco, yields were apparently severely affected by the transfer of glyphosate from desiccated cereals to the transplanted tobacco. The glyphosate was sprayed two weeks in advance of transplanting (Shilling et al, 1986).

SUMMARY

Cereal residues derived from fall or spring plantings suppress weeds, particularly summer annuals. However, suppression is short lived, and usually requires additional weed control practices to make the system practical. Soil coverage is the most critical factor determining weed suppression but other factors include biomass of the residue, stage of growth, color, herbicide used to kill the crop, and amount of soil disturbance. Mechanisms which affect the weed seed microenvironment include light, temperature, allelopathy, soil moisture, seed predation, and disease.

Crops also are affected by cereal residues. Reports include both positive and negative aspects. Difficulties establishing a seedbed and low soil temperatures are the most severe problems but include other factors such as disease incidence and allelopathy. Positive affects on crops are attributed primarily to increased soil moisture but include a reduction of pests.

Many of the same mechanisms affecting weeds also affect crop plants. The success of a system will depend on the differential response of the crop and weeds to the cereal residue.

CHAPTER 3

WEED SUPPRESSION WITH CEREAL RESIDUES IN A CONSERVATION TILLAGE CUCUMBER PRODUCTION SYSTEM

ABSTRACT

The weed suppression afforded by cereal residues in a no-till cucumber production system was determined. Fall-planted cover crops were desiccated in the spring and cucumbers direct-seeded into the mulch. Weed suppression was evaluated with and without a broadcast application of glyphosate over the cucumbers just before emergence. Without glyphosate applied at cucumber emergence, cereal residues did not effect weed dry matter or density six weeks after cucumber planting compared to no-till, no-residue treatments. Cereal residues with glyphosate significantly reduced weed dry matter accumulation to a level comparable with conventional tillage; weed density suppression was apparent only in treatments with high residue density. At last cucumber harvest, weed control was unacceptable in all residue treatments. Early season growth of cucumbers was slightly reduced by no-till treatments with and without residue. Cucumber yield was reduced by weed competition. Though weed suppression was adequate in the early season, cereal residues must be complimented with other strategies to make this a viable system.

INTRODUCTION

Weed suppression with residues of small grain cover crops has received considerable attention in light of the increased use of conservation tillage systems in the midwest and the allelopathic nature of cereals (Barnes and Putnam, 1983; Shilling et al, 1986). Cereal residues suppress weeds by modifying the light, temperature, chemical, and moisture environment around germinating seeds (Barnes et al, 1987; Teasdale et al, 1991). Residues from cereal cover crops reduced weed density by 80 percent early in the season compared to plots with no residue; but residues had little effect on late season weed suppression (Worsham, 1991). Residue of a killed rye (*Secale cereale*) cover crop improved the efficiency of atrazine and metolachlor in sweet corn and improved weed control over no-till without residues for a full season (Mohler, 1991).

Challenges introduced by cereal residues in no-till systems include interference with cultural practices, lower soil temperature in the spring, and increased slug damage (Weston, 1990). The later two are prominent concerns in the maritime climate of the Pacific Northwest (Petersen, 1986). Another difficulty is the lack of equipment that effectively direct-seeds vegetable crops through cereal mulches into untilled soil. Good seed-to-soil contact is critical for successful crop establishment while minimal soil disturbance is required to prevent weed emergence (Froud-Williams et al, 1984; Weston, 1990).

Cucumber producers in the Willamette Valley of Oregon rely primarily on preplant tillage strategies, a single application of a broad spectrum herbicide such as glyphosate or paraquat before cucumber emergence, cultivation, and hand hoeing to control weeds. Although preemergence herbicides are used occasionally, several are in disfavor because of poor weed control spectrum, varied responses to climatic conditions, crop injury, and crop rotation restrictions. Chloramben (Amiben), the herbicide commonly used in the past, is no longer available. An alternative strategy to control weeds manages cereal cover crop residues in a no-till system. While this system introduces difficulties, cover crops in no-till systems address some of the deleterious aspects of conventional tillage systems. Benefits include reduced soil erosion, less water and soil organic matter loss, reduced fossil fuel consumption, improved soil structure, and nutrient recycling (Blevins, 1983;

McDiff, 1986; Lal et al, 1991). Additionally, cucurbit crops are less affected by no-till and mulched conditions than crops such as snap beans and peas (Weston, 1990).

The objectives of this experiment were: to determine the extent of weed suppression afforded by several cereal residues in a minimum-tillage system at 6 and 12 weeks after cucumber planting, with and without the use of a broad spectrum, post-plant herbicide; evaluate the effect of cereal residues on cucumber growth and yield; compare the weed suppression characteristics of several cereal residues; and determine if cereal cover crop residues with conservation tillage may be appropriate as a weed control strategy in production of processing cucumbers in the Willamette Valley of the Pacific Northwest.

MATERIALS AND METHODS

An experiment was initiated at the Oregon State University vegetable farm in the fall of 1991 on a 'Chehalis' silt clay loam soil. The soil was plowed and disked in September and cereals seeded on October 1 or 18 into plots 3 by 15 m established in a randomized complete block design with five replications. Cereal seeds were spread with a Gandy fertilizer spreader; the soil rotovated to 4 cm to incorporate the seed and rolled. Four varieties of spring barley (*Hordeum vulgare*: 'Galt', 'Micah', and 'Steptoe') and Galt barley plus crimson clover were sown on October 1 and irrigated one time after sowing. Galt barley was sown again on October 18 along with wheat (*Triticum aestivum* 'Stephens') and rye (*Secale cereale* 'Wheeler'), just before the first fall rain. Galt barley, Steptoe barley, and Wheeler rye were sown at 484 seeds m^{-2}. Stephens wheat was sown at 320 seeds m^{-2}. The seed rate of Micah barley was adjusted to compensate for the germination of 48 percent. In the barley plus clover plot, seeds were sown at 280 and 300 seeds m^{-2}, respectively. Two plots were not seeded with cereals and remained fallow during the winter and spring for the conventional-tillage and winter fallow, no-till treatments. The plots were not fertilized before planting the cereals because they were preceded by heavily fertilized vegetable crops.

Propiconazole, a fungicide, was applied to the barley plots at a rate of 0.3 l ha^{-1} in February because barley scald disease caused patches of cereal to begin to senesce. The winter season was exceptionally warm and the spring barley varieties did not winter-kill. Therefore, all the barley was killed with glyphosate on March 21, at or near boot stage (Table 3.1). The winter fallow and Stephens wheat plots were treated with glyphosate on April 30. The conventional tillage treatment was mowed on April 3 and rototilled April 7 and at cucumber seeding.

Cucumber seeds (var. Pioneer) treated with metalaxyl and thiram were planted with a cross-slot seeder on May 16, 1992 in rows spaced 1.8 m perpendicular to the length of the cereal residue plots. Two weed control treatments were superimposed over the main cover crop treatments, perpendicular to the length of the cereal plots. This formed a strip plot design with 1.8 by 3.0 m subplots. Main effects were cover crop treatment and weed control 'level'. 'Level 1' was treated with glyphosate (1.12 kg ha^{-1}) just before cucumber emergence (5 days after cucumber seeding). After the 6 week weed evaluation, sethoxydim (0.31 kg ha^{-1}) was applied and plots hoed in a way comparable to that given in the conventionally managed plot. 'Level 2' had no additional weed control other than the herbicide that killed the cereal in March or April. Plots of the conventional tillage treatment in 'Level 1' were cultivated 4 and 6 weeks after planting the cucumbers.

Fertilizer (NPK; 12-29-10) was banded at planting at 11 g m^{-1} of row. After evaluation of seedling emergence (18 DAP), cucumber plants were thinned to 12 cm. Additional fertilizer (NPK; 12-29-10) was surface-banded 15 cm on both sides of the row at 4 WAP at 224 kg ha^{-1}. And 132 kg ha^{-1} of urea was surface banded at 37 DAP as the cucumbers began to vine. The row of cucumber plants in each sub-plot was reduced to 1.5 m in length 6 WAP. Slug bait (metaldehyde, 4%) was broadcast on the whole area at approximately 33 kg ha^{-1} on May 19 and banded next to the row at the same rate on May 24. No additional insecticides or fungicides were required.

Cover crop measurements. Three quadrats were designated near the center of each main plot for cereal cover crop and weed sampling. One quadrat of each main plot was randomly selected at three sampling periods; weeds and cover crop plants from 0.5 m^2 (100 cm by 50 cm) were counted, removed, dried, and weighed. The three sampling periods were: December 15 for all treatments (winter census); March 15 for barley, March 24 for rye and April 23 for wheat and the winter fallow plot (herbicide treatment census); and May 19 for all treatments (residue sampling). All vegetation was dried for four or more days at 45 C and weighed.

Weed evaluation. Effects of the cereal residue only (excluding in-row disturbance effects) on weed density and dry matter were measured at 6 WAP by counting, removing, drying and weighing weeds from two 0.06 m^2 circles placed on opposite sides at 1.5 m from the end of the cucumber row in each plot. Weed density and dry matter were assessed again at last cucumber harvest (12 WAP) from between and within cucumber rows. Two quadrats, each 50 by 50 cm (0.25 m^2) were placed on both sides of the row and weeds counted, removed, dried, and weighed. A 10 by 50 cm area (0.05 m^2) of weeds was cut from directly within the row and between the other two quadrats.

Cucumber growth and yield. Cucumber seedlings were counted 18 DAP from 0.6 m of row at the center of each plot. Seedlings were thinned to equal densities within each plot. Percent reduction in growth of cucumber plants in relation to the conventional tillage treatment was visually assessed at 35 DAP. Cucumbers were harvested, graded and weighed from 1.5 m of row six times at intervals of three to four days.

Data were analyzed with the general linear model (GLM) of SAS (SAS Institute, 1987). Data were checked for normality by comparing residuals and predicted values and natural log transformed if necessary. All weed data were log transformed. Data from block #1 were excluded from the analysis of weed density and weight because of a very poor stand of cereals resulting from poor fertility and disease that contributed to outliers and a significant blocking effect. Block #1 was included in cucumber yield analysis because no blocking effect was apparent. Weed suppression potential of the cereal residues was evaluated by regressing weed dry matter versus cereal dry matter, and the slopes of the regression equations were contrasted using contrast procedures of the GLM of SAS.

RESULTS AND DISCUSSION

Cover crop growth. Galt and Steptoe barley seeded October 1 produced the most dry matter by December 15. Micah barley dry matter was less because seed germination and vigor was reduced. Planting cereals 18 days later significantly decreased dry matter accumulation by December 15 and provided very little soil cover. Barley scald symptoms began to appear in the Northwest corner of the trial but primarily affected barley in block #1, apparently due to poor soil fertility.
Weed density suppression: 6 WAP. Cereal cover crop residues on the soil surface reduced average weed density by 65 percent compared to the same soil conditions without cereal residue (Table 3.2, level 2)[1]. This weed density reduction is less than the 78 and 90 percent reduction reported by others (Teasdale et al, 1991; and Putnam et al, 1983; respectively). Eight weeks passed between the barley kill date and cucumber seeding in this experiment, compared to 2 to 4 weeks in the cited examples. Barley booted in early March because of the warm winter. None of the individual treatments were an improvement over the no-till, no residue treatment.

Applying glyphosate over the residue plots just before cucumber emergence (Table 3.2, level 1) decreased weed density an average 16 percent at 6 WAP, although the main effects term indicates this difference is insignificant (Table 3.4). In this scenario, all residue treatments were an improvement over the no-till no

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[1] Single degree of freedom contrast between treatments with residue and the untilled treatment without cereal residues in Level 2 ($P=0.10$).

residue treatment, but only Stephens wheat and Micah barley compared with the conventionally tilled and cultivated treatment. Stephens wheat and Micah barley reduced weed density by 81 percent compared to the no-till, no residue treatment.

Weed dry matter suppression: 6 WAP. The presence of cereal residue on the soil surface increased weed dry matter an average of 34 percent compared to the treatments without residue, although a single degree of freedom contrast indicates this is not a significant difference (Table 3.2, level 2)[2]. Again, this differs from the 40, 73 and 84 percent reductions reported by others (Putnam et al, 1983; Barnes and Putnam, 1983; and Smeda and Putnam, 1988, respectively). None of the residue treatments were an improvement over the no-till, no residue treatment. Wheeler rye residue effectively suppressed both weed emergence and dry matter accumulation; but it also maintained excessive soil moisture because of its impermeable nature. Conversely, the soil under Stephens wheat residue was very dry even though residue density was substantially more than rye. The longer period of evapo-transpiration in the spring before desiccation with wheat (nearly 4 weeks) was apparently a key factor. The excessive soil moisture under rye residues provoked malfunction of the cross-slot coulter, consequently dragging the residue rather than slicing through cleanly. This caused more soil disturbance than in other residue treatments, which encouraged weed germination and growth, resulting in patches.

Applying glyphosate over the plots just before cucumber emergence reduced weed dry matter an average of 90 percent compared to the treatments without glyphosate, though the effect was inconsistent across residues (Table 3.2, level 1 and 2). A 'level' by 'residue' interaction for weed dry matter was apparent even when data analysis only included treatments with cereal residues (Table 3.4; P=0.003). The later kill dates and large amount of residue of Stephens wheat and Wheeler rye contributed to the interaction. Applying glyphosate over cucumbers

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[2] Contrast of weed dry matter 45 DAP of treatments with cereal residue against the untilled treatment without residue in Level 2 (P=0.70).

prior to emergence improved weed dry matter suppression so that all residue treatments except Steptoe barley were statistically equivalent to the conventionally tilled and cultivated treatment.

Weed suppression: 12 WAP. Cereal residues effectively suppress many broadleaf, summer annual weeds. However, species of annual grasses and perennial weeds are less inhibited by cereal residues or mulches (Putnam et al, 1983). Therefore, sethoxydim was applied after the '6 WAP' census. At 12 WAP, weed density in Steptoe barley plots was comparable to the level in the tilled and cultivated treatment but weed dry matter was nearly 5 times greater. None of the residue treatments of 'level 2' compared to the weed dry matter in the tilled and cultivated treatment (Table 3.3).

The effect of soil disturbance on weed germination and growth is well documented and is a factor of light induced germination and improved seed to soil contact (Froud-Williams,1984; Wesson and Waring, 1968; Shilling, 1991). The cross-slot seeder caused very little soil disturbance during seeding, but even this disturbance precipitated a significant flush of weeds, predominately summer annuals. Average in-row weed density and dry matter were 77 and 112 percent greater than weed density and dry matter between rows, respectively (Table 3.3). Herbicides decreased in-row weed density by 50 percent in the residue treatments but had no effect on weed dry matter (Table 3.4).

Weed suppression potential. One objective of this study was to compare the weed suppression potential of several cereal residues without the influence of cereal dry matter accumulation at 6 WAP. Residue dry matter and soil coverage at crop seeding are primary determinants of weed density reduction (Teasdale, 1991). From the perspective of a producer, percent soil coverage is impractical for predicting weed suppression because it can not be estimated until after the cover crop is killed and lying on the soil. But cover crop dry matter can be measured before the cereal is killed. Therefore, models can be constructed for each cereal cover crop to predict weed suppression at a particular dry matter.

Weed density of the residue treatments in 'level 1' at 45 DAP was correlated with cereal residue dry matter at crop seeding. Then regression equation slopes for each residue treatment were compared using contrast analysis procedures of SAS (SAS Institute, 1987). Data from 'level 1' were used for two reasons. First, though the cover crops were killed at a similar growth stage, weed density in barley was much greater than rye and wheat at crop planting because of different time periods from cereal kill to crop seeding. Second, glyphosate applied over the residues just before crop emergence produced weed free plots, 'resetting' residues to the same weed level. The weakness to this supposition is that conditions prior to herbicide application such as soil moisture and temperature may have influenced the outcome 6 weeks later, at the date of weed density and dry matter sampling. Therefore, the most reliable comparisons should be between those cereals that were killed on the same date, specifically the comparisons among barley varieties. Another weakness to this analysis is the limited amount of data; weeds were counted from two samples in each plot of each treatment in five replications (10 samples for each treatment, but five data points) and the samples were averaged together to meet the criteria for regression analysis.

Orthogonal contrasts were made between the linear regression equation slopes to the various cereals in consideration of the nested configuration of these treatments. There is little evidence to suggest differences between the weed suppression characteristics of Galt barley, Micah barley, Stephens wheat, or Wheeler rye (Table 3.6). However, the weed density reduction of Steptoe barley per unit of residue was less than Micah or Galt barley (Figure 1), also apparent in field observations. The comparison of barley with rye or wheat may be particularly unreliable as the kill date was 3 and 5 weeks later, respectively, than the kill date for barley. Soil conditions were quite different under rye, wheat, and barley residues. A visual comparison of weed density versus residue dry matter for the varieties planted and killed on the same date indicates a similar trend (Figure 1). However, Micah barley growth was less succulent than the other barley varieties and tended to boot earlier. Galt and Steptoe barley grew vigorously and had very similar growth habits.

Crop effects. Cucumber seedling emergence was greatly restricted by mulch levels that were above 6.5 t ha^{-1} (Table 3.5). Crop growth at 5 WAP was less than conventional tillage for all treatments, including no-till without residue. This indicates that a variety of factors were operating. The severe crop reduction noted in Wheeler rye was due to very moist soil conditions encountered when planting cucumber seeds under the residue, and to seed predation in one block. Seedling diseases may have been encouraged by the wet soil conditions. Slug damage was not a factor in this experiment. The very dry, warm spring and slug bait effectively suppressed slug populations to the extent that slug damage was not a factor in this experiment. The same weather conditions may have reduced the expected negative effect of lower soil temperatures on crop growth.

At 12 WAP, cucumber yield was significantly less for all treatments with residue compared to conventional tillage.

SUMMARY AND CONCLUSIONS

Cereal residues of fall planted cover crops without additional weed control measures had no effect on weed density or dry matter at 6 WAP, although trends indicate that weed density was more affected than weed dry matter. Lack of weed suppression was primarily due to the long period between the date the cereal was killed and the date cucumbers were planted; a warm winter and spring caused the spring cereals to bolt in mid March and necessitated an early kill of the barley.

Applying glyphosate over the cucumbers just before emergence significantly reduced weed dry matter, particularly for low residue levels, but had no effect on weed density at 6 WAP. Stephens wheat suppressed weed dry matter accumulation and density comparable to conventional tillage with cultivation 6 WAP, due to the high residue level and late kill date. Galt and Micah barley were more efficient than Steptoe barley in weed suppression on a residue basis. Weed pressure was extreme in this experiment and weed control for the full season was totally inadequate for all residue treatments 12 WAP.

Additional weed control tactics must be employed to make this a viable system. At 6 WAP, cultivation would have been possible in residue plots of 4 t ha^{-1} or less, but may have required specialized machinery. Flailing of the residue would increase decomposition of the residue but may have increased weed seed germination. The larger problem was weeds emerging in the row, prompted by the disturbance of the cross-slot planter. Hand hoeing is difficult in no-till conditions. Banding of herbicides may be the only alternative, although this scenario is unappealing for cucumber production because of the unavailability of reliable and effective preemergence herbicides.

Cucumber growth 5 WAP was reduced by both no-till conditions and residues on the soil surface. Cucumber yield was 52 percent greater in conventional tillage than the best residue treatment, though the primary factor was weed competition.

A plausible scenario that requires testing includes cereal mulches killed 2 to 3 weeks ahead of cucumber seeding, strip tillage with herbicides banded over the row, and follow-up directed spray of a non-selective herbicide or cultivation with specialized cultivation equipment to kill weeds emerging through the mulch, particularly the interface between the tilled strip and mulch. However, the benefits of reduced tillage may be outweighed by the cost and inconvenience of this system. The negative impact of residues on soil temperature could be partially alleviated, along with the threat of slug damage, while the soil and water conserving properties of the system maintained. Additionally, cucurbit crops with a more competitive nature such as pumpkin or zucchini may be better adapted to this system.

Figure 3.1. Weed drymatter response to residues of Galt, Micah, and Steptoe barley. Cereals were planted on Oct. 1, 1991, killed with herbicide on March 15, 1992, and treated with glyphosate again on May 19, just after cucumbers were planted. Weed drymatter was determined 6 weeks after planting. Each data point is the average of two samples.

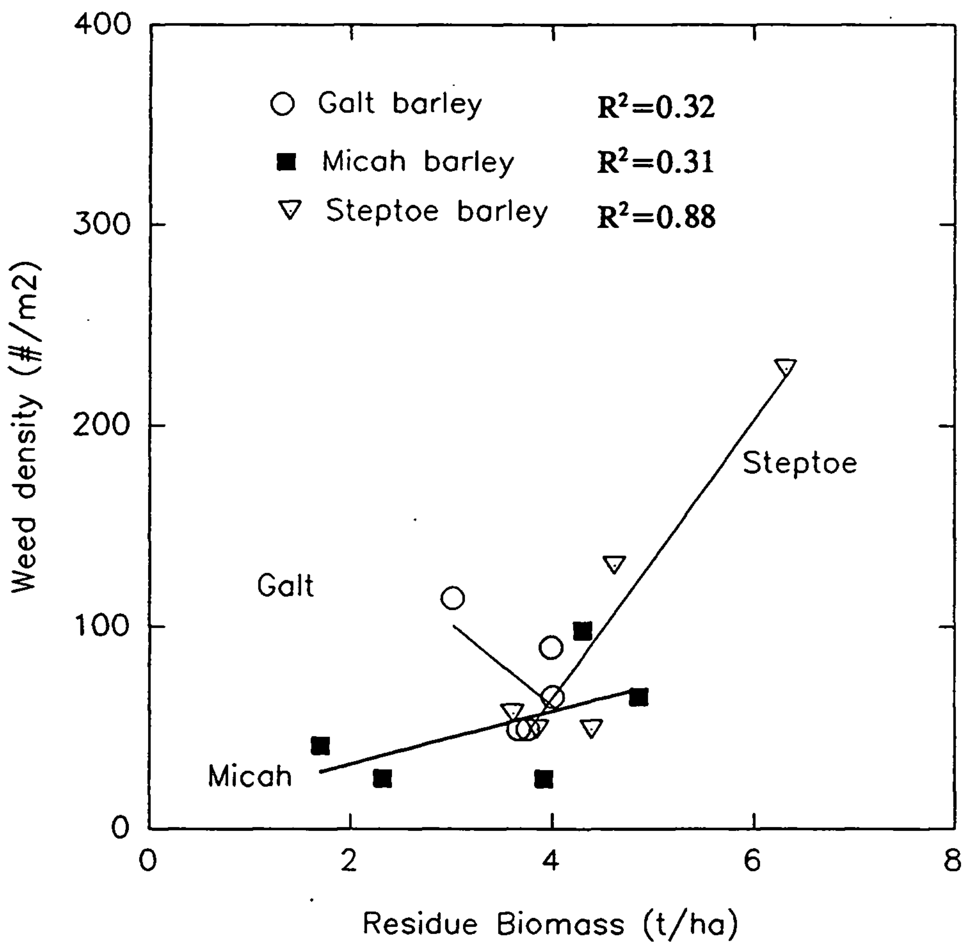

Table 3.1. Treatment summary: dry matter accumulation of cereals and weeds on Dec. 15 1991, at herbicide application/cereal kill date, and cucumber seeding May 15, 1992.

Cereal, variety, and planting date	Dry matter Dec. 15, 1991 ($g/0.5m^2$)		Spray date; growth stage; and height (cm.) at spray date.	Dry matter at spray date ($g/0.5m^2$)	
	Cereal	Weeds		Cereal	Weeds
Spring barley Galt (Oct. 1)	69.1 a	0.6 c	March 20, flower, 91	243	0.6
Spring barley Galt (Oct. 18)	4.5 c	3.4 c	March 20, flower, 88	144	4.6
Spring barley and clover Galt and Crimson Clover (Oct. 1)	46.7 b	1.1 bc	March 20, flower, 85	218	11.2
Spring barley Micah (Oct. 1)	40.9 b	3.0 bc	March 20, boot, 61	183	21.2
Spring barley Steptoe (Oct. 1)	65.5 a	1.0 bc	March 20, preflag, 81	272	1.0
Winter rye Wheeler (Oct. 18)	13.5 c	0.7 c	April 3; pre-boot	391	0.0
Winter wheat Stephens (Oct. 18)	4.2 c	0.4 c	April 24; pre-boot	503	10.4
No-till, no cereal residue	0.0 c	5.6 a	April 24	0.0	117.0
Conventional, no cereal residue	0.0 c	8.7 c	April 3, mowed April 7, tilled	0.0	83.2

Table 3.2. Effect of cereal residues on weed density and dry matter in a conservation tillage system at 6 weeks after cucumber seeding.

Cereal and planting date	Weed density [a]		Weed dry matter [a]		Cereal residue[b]
	Level 1 [c]	Level 2	Level 1	Level 2	
	—— No. m^{-2} —		—— g m^{-2} ——		- t ha^{-1} -
Galt barley (Oct 1)	91 b	111 b	13.7 ab	164 c	3.7
Galt barley (Oct 18)	110 b	81 b	13.4 ab	171 c	3.2
Galt and clover (Oct 1)	120 b	153 bc	13.4 ab	242 c	4.0
Micah barley (Oct 1)	60 ab	193 bcd	16.3 ab	218 c	3.9
Steptoe barley (Oct 1)	114 b	73 ab	23.6 bc	119 c	4.8
Wheeler rye (Oct 18)	94 b	71 ab	11.2 ab	28 c	6.9
Stephens wheat (Oct 18)	61 ab	100 b	5.5 a	30 c	8.8
No-till, no residue	456 d	323 bcd	22.0 ab	103 c	0.8
Conventional tillage	33 a	335 cd	7.8 a	65 c	0

[a] Values in these two columns followed by the same letter are equal ($P<0.05$), means separated using ls means procedures of SAS.
[b] Residue dry matter at cucumber seeding.
[c] Level 1 = glyphosate 5 DAP; sethoxydim 6 WAP.
Level 2 = glyphosate only used to kill cereal.

Table 3.3. Weed density and dry matter at 12 weeks after cucumber seeding in a conservation tillage system.

Cereal and planting date	Weed density				Weed dry matter			
	Between rows[a]		Within rows		Between rows		Within rows	
	Lvl 1[b]	Lvl 2	Lvl 1	Lvl 2	Lvl 1	Lvl 2	Lvl 1	Lvl 2
	No. m^{-2}				g m^{-2}			
Galt barley (Oct 1)	42 e	41 e	63	153	600 d	351 cd	673	1605
Galt barley (Oct 18)	36 de	36 de	63	101	522 d	700 d	673	1375
Galt and clover (Oct 1)	37 e	47 e	37	134	440 cd	700 d	740	1230
Micah barley (Oct 1)	23 cde	33 cde	23	91	291 bcd	510 cd	240	1702
Steptoe barley (Oct 1)	13 abc	17 bc	53	48	221 bc	416 cd	801	904
Wheeler rye (Oct 18)	18 abc	32 cde	39	101	535 d	758 d	1212	2548
Stephens wheat (Oct 18)	26 bcd	22 bcd	63	57	328 bcd	323 bcd	1908	2827
No-till, no-residue	22 bcd	35 cde	53	43	192 b	526 d	259	971
Conventional till	12 a	108 f	39	87	47 a	664 d	64	721
				NS				NS

[a] Values in these two columns followed by the same letter do not differ (means separated using ls means comparisons of SAS, P=0.05)

[b] Level 1: glyphosate 5 DAP; sethoxydim 6 WAP.
Level 2: glyphosate only used to kill cereal.

Table 3.4. Anova summary of weed density and dry matter data.

	6 WAP	12 WAP	
	Between rows	Between rows	Within rows
Dry matter			
Treat	**[a] (*)[b]	NS	NS (NS)
Level	NS (*)	NS	NS (NS)
Treat*Level	** (**)	* (NS)	NS (NS)
Density			
Treat	NS (NS)	NS	NS (NS)
Level	NS (NS)	NS	NS (*)
Treat*Level	** (NS)	** (NS)	NS (NS)

[a] NS, *, **; not significant, significant at p=0.05 and 0.01.

[b] The interaction term in parenthesis only includes cereal residue treatments.

Table 3.5. Emergence, growth, and yield of cucumbers planted in cereal cover crop residues in a conservation tillage system.

Treatment	Crop emergence (18 DAP)[a]	Reduction in plant growth (5 WAP)[b]	Cucumber harvest: Cucumber fruit, Level 1[c]	Cucumber harvest: Cucumber fruit, Level 2	Cucumber harvest: Cucumber weight, Level 1	Cucumber harvest: Cucumber weight, Level 2
	- No.m^{-1} -	- % -	- No. m^{-1} [d] -		— t ha^{-1} [d] —	
Galt barley (Oct 1)	93**	13*	34 efg	12 g	14.5 de	4.9 f
Galt barley (Oct 18)	66	10	35 def	17 fg	15.9 d	5.5 f
Galt and clover (Oct 1)	79	10	36 d	14 g	15.6 d	4.8 f
Micah barley (Oct 1)	69	10	56 bc	18 fg	22.5 c	7.3 e
Steptoe barley (Oct 1)	69	10	40 cde	19 fg	17.6 cd	7.9 e
Wheeler rye (Oct 18)	36*	58*	40[x]	11[x]	13.8[x]	3.7[x]
Stephens wheat (Oct 18)	38*	45*	48[x]	27[x]	19.3[x]	9.3[x]
No-till	88	10	63 b	39 cd	25.8 b	18.4
Conventional tillage	72	0	84 a	18 g	34.3 a	7.6 e

[a] Average emergence of Level 1 and Level 2.
[b] Level 1 only.
[c] Level 1 = glyphosate 5 DAP; sethoxydim 6 WAP.
Level 2 = glyphosate only used to kill cereal.
[d] Values in these two columns followed by the same letter do not differ (means separated using ls means comparisons of SAS, P=0.05).
* Figure in this column followed by (*) differ from the conventionel control (Fishers Protected LSD, P=0.05).
[x] Insufficient date to make comperison.

Table 3.6. Orthogonal contrasts of regression slopes for weed dry matter suppression characteristics of cereal residues 6 weeks after planting.

	Residue treatments.							
Comparison	Galt barley & C. clover	Galt barley Oct 1	Galt barley Oct 18	Micah barley	Steptoe barley	Wheeler rye	Stephens wheat	P > |T|
Slope[a]	0.24	-29.1	-6.53	16.1	69.0	50.03	-12.71	
Galt barley vs Micah barley	1[b]	1	1	-3	0	0	0	0.32
Galt barley vs Steptoe barley	1	1	1	0	-3	0	0	0.02
Micah barley vs Steptoe barley	0	0	0	1	-1	0	0	0.06
Micah barley vs rye and wheat	0	0	0	2	0	-1	-1	0.93
Galt barley vs rye and wheat	2	2	2	0	0	-3	-3	0.41

[a] Slope= ▲ weed density (g m^{-2})/ ▲ residue dry matter (t ha^{-1})
[b] Contrast coefficients.

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CHAPTER 4

MECHANISMS AFFECTING CUCUMBER GROWTH IN A CONSERVATION TILLAGE SYSTEM

ABSTRACT

Cereal residues modify soil and boundary layer temperatures, soil moisture, and the light and chemical environment around emerging seedlings. This experiment quantified the effects of cereal residues on cucumber growth in untilled soil. A mulch of *Populous excelsior* (PE) wood shavings significantly increased average plant weight compared to a natural barley (*Hordeum vulgare*) residue even though soil temperatures were equal. An additional treatment that included both barley residue and PE indicated that PE had a positive effect on plant growth. Tillage increased cucumber emergence and plant growth compared to no-till conditions. Reduced plant growth with barley was apparently due to no-till conditions rather than factors caused by the cereal residue such as lower soil temperature.

INTRODUCTION

Cereal residues and conservation tillage systems impact the growth of crops by modifying soil temperature, moisture, disease dynamics, and the light environment of germinating seedlings (Sumner et al, 1986; Teasdale, 1992).

Cereal residues reduce mean soil surface temperatures in the zone where seeds germinate and begin to grow (Mohler, 1992). Cold soils slow germination and emergence while lower air temperature above the soil surface slows the rate of cell division in the apical meristem (Fortin, M.C. and Pierce, 1991). In northerly locations, this may be a serious detriment to crop performance. For instance, sweet corn yield was reduced by 31 percent in no-till, flailed cereal plots compared to conventionally managed plots, and 16 percent compared to strip tillage in the Pacific Northwest (Petersen et al, 1986). The yield decrease was attributed to lower soil temperatures, but the inefficiency of the planter in no-till conditions, slugs, and wet soils also were cited as factors (Petersen, 1986).

Wilcox and Pfeiffer (1990) demonstrated in a controlled environment experiment that cucumber growth was severely retarded when soil temperatures dropped only 2.2 C from 14.5 to 12.3 C. Seedling root growth varied little between these two temperature regimes. Additions of phosphorus compensated somewhat for the decrease in top growth of cucumbers at the lower soil temperatures.

Mulches may reduce yields of crops through allelopathy, but this connection is tenuous and easily confused with other factors such as disease incidence (Raimboult et al, 1990). Compounds were extracted from cereal herbage that decreased seed germination, and inhibited root and shoot growth in bioassay experiments on crop and weed seeds (Barnes and Putnam, 1983; Barnes and Putnam 1986). In simulated no-till conditions with cereals grown in pots, *Populous excelsior* wood shavings were substituted for cereal residues as a non-allelopathic medium in allelopathic studies because there was no apparent allelopathic effect of PE on seed germination and seedling emergence (Barnes and Putnam, 1983; Putnam and DeFrank, 1983; Putnam et al, 1983). Also, these same researchers measured light and temperature under equal weights of cereal residue and PE and found light and temperature conditions nearly equal, supporting the use of PE as a practical substitute for cereal residue that would emulate all cereal residue properties except the allelochemical fraction.

The objective of this experiment was to quantify the effect of cereal residues on cucumber growth in untilled soil. Factors included the effect of soil temperature, activated charcoal, metalaxyl, and tillage on cucumber emergence and growth.

MATERIALS AND METHODS

An experiment was initiated at the Oregon State University vegetable farm in the fall of 1991 on a sandy loam soil. The soil was plowed and disked in September to accommodate cereal seeding. Barley seeds (*Hordeum vulgare,* 'Galt') were spread over an area 3 by 30 m with a Gandy fertilizer spreader at 484 seeds m^{-2} on October 1, 1991, and the soil rotovated and rolled to cover the seed. The area received one irrigation in October. Plots were not fertilized before sowing the cereal because they were preceded by heavily fertilized vegetable crops.

Barley was killed on March 21, 1992 with glyphosate at 2.2 kg ai ha^{-1}. On May 17, 1992, plots of 0.70 m^2 were designated and treatments were assigned in a completely randomized design, except for the no-till treatment without cereal. The no-till treatment without residue was planted in an area in the center of the main plot that had not been planted to barley the previous fall. Barley residue dry matter at time of seeding was approximately 3.8 t ha^{-1}.

Before cucumber seeding, a cross-slot planter was pulled across the plots depositing fertilizer (NPK: 12-29-10) at 11 g m^{-1} of row two inches from the soil surface. Cucumbers were planted on May 19 next to the cross-slot row using a no-till punch which made a cone-shaped hole 5 cm in diameter and 5 cm deep to minimize seed contact with the cereal residue. The hole was filled half full with soil, three seeds placed in the hole and the hole filled to the top with soil. The distance between seed holes was 23 cm. At 24 days after planting (DAP) 40 g m^{-1} row of fertilizer (NPK: 12-29-10) was surface banded next to the row of cucumbers. Slug bait was broadcast on plots twice to eliminate slug damage.

Treatment descriptions. The cereal mulch was maintained undisturbed for treatments 1,3, 5 and 6 (Table 4.1). The soil was turned with a spade in treatment 7 and raked to smooth the surface. Cereal residue was removed from plots that did not require a mulch (treatments 4,7,and 8) and weighed. A small amount of this straw and *Populous excelsior* wood shavings (PE) were dried for 48 hours at 46 C.

PE was applied to plots of treatments 2 and 3 at a rate equivalent to the average dry weight of cereal residue that was removed from all plots, and secured to the ground with plastic netting. Treatments without roots and residue were located where cereals were not seeded.

The soil temperature difference between barley residue and PE mulch treatments was monitored by placing the temperature sensors of a chronometer 2.5 cm under the soil surface in a representative plot of barley and PE. Additionally, soil temperature was monitored in all plots at 3 or 4 day intervals at either 9:00 AM or 4:00 PM with a hand-held digital probe at 2.5 cm. Equal dry weights of barley residue and PE did not result in the same soil temperature. An additional 37 percent of PE was needed compared to barley residue on a dry weight basis to equilibrate the soil temperatures between the barley residue and PE mulched plots. Researchers previously demonstrated that equivalent weights of PE and cereal residue equally reduced light infiltration and soil temperature (Barnes and Putnam, 1983). However, this was under simulated field conditions.

Activated charcoal and soil were mixed (2 % w/w) and placed in the seed holes in the charcoal treatment. The effect of metalaxyl (Apron) was assessed in the fungicide treatment by treating seeds at the rate of 0.6 g kg^{-1} of seed.

Plots were maintained weed-free to eliminate competition. Weeds were pulled or clipped to reduce possible damage to the crop. Measurements included number of emerged seedlings and plant dry matter. Residues on the soil surface were manipulated around emerging seedlings to avoid shading of emerging seedlings or impediments to growth. Plants were harvested at 35 DAP, dried, and weighed. The mulch from the barley and rye residue plots was also collected and dried. Data were analyzed using the General Linear Model procedure of SAS (SAS Institute, 1987). Transformation of data was not required based on comparison of predicted versus residual values. Treatment 8 was not randomized within the experiment; therefore, the standard error of this treatment was not included in the pooled error term.

RESULTS AND DISCUSSION

The soil temperature difference at 2.5 cm between barley and PE plots averaged nearly zero according to temperature data taken with the digital probe (Table 4.2). This was confirmed by the temperature chronometer (data not shown). Still, a 65 and 50 percent increase in total plant weight (TPW) and average plant weight (APW), respectively were found where PE was substituted for barley residue. Two explanations are plausible. First, an undefined property of the residue such as allelotoxin release or factors associated with no-till conditions were responsible for the yield decline in growth. Second, PE contributed positively to the growth of the cucumbers through modifications of the seed microenvironment such as light penetration, soil boundary layer conditions, and soil moisture. The second hypothesis is supported by the results of the PE plus barley residue treatment, which also significantly increased APW over the barley residue treatment. We observed that the color of the PE mulch was lighter than the barley residue. Reflectance also was greater as determined by a light meter (data not shown), which possibly affected plant growth. These results challenge the use of PE as a practical substitute for cereal residues under field conditions.

The outcome of this experiment also suggests that the soil temperature difference caused by cereal residues may not be a critical factor in plant growth in untilled soil. If reduced soil temperature inhibited growth, a similar inhibition would be expected under PE residues.

There is little evidence to support the hypothesis that allelotoxins within the cereal residue affected plant growth because the PE mulch apparently increased cucumber growth. Additionally, activated charcoal had no effect on emergence or APW, though a negative trend was noted. The rate of charcoal used may have been excessive and discouraged growth. Activated charcoal detoxifies chemicals by tightly adsorbing active compounds (Shilling et al, 1992). If allelotoxins were present in the soil, activated charcoal should have rendered them inactive.

The evidence then, points to untilled conditions as a major factor in determining plant growth rather than allelopathic or temperature effects. Tillage increased APW compared to no-till, even though soil temperature of the treatments were equal. Also, APW of the no-till, no residue treatment was nearly equal to the barley residue treatment, though soil temperature difference between the treatments was significant (Table 4.2). However, emergence in the no-till, no residue treatment was greater than the barley residue treatment. Soil tillage dramatically improved plant growth but not emergence compared to the no-till treatments, with or without cereal residue. But even this treatment did not exceed the growth in PE plots. Treating seeds with metalaxyl had no effect on emergence or APW. APW in the treatment that was not planted to cereal cover crops (without cereal roots) was significantly depressed. Though several explanations are plausible, two are forwarded here. First, the presence of the cereal roots may have positively affected cucumber growth even though emergence was unaffected. Alternatively, the cereal residues prevented soil compaction.

SUMMARY AND CONCLUSIONS

This experiment infers that soil temperature reduction caused by cereal residues of 3.8 t ha^{-1} was insignificant in the observed crop growth reduction, and that untilled soil was the primary factor. Weather conditions during the spring of 1992 were quite warm, however. In normal years, soil temperature reduction may have been more significant. Replacing barley residue with PE increased cucumber growth to a level equivalent to the tilled conditions. Cucumber growth in the barley plus PE treatment indicates that PE had a positive affect on plant growth. Activated charcoal and cucumber seed treated with metalaxyl had no effect on emergence or growth.

Table 4.1. Summary of treatments for effects of cereal residue, *Populous excelsior* (PE), activated charcoal, metalaxyl, and tillage on cucumber growth in a conservation tillage system.

	Mulch	Mulch rate	Tillage	Activated charcoal	Metalaxyl	Cereal roots	Comments
1.	Barley	1X	-	-	-	-	Natural residue, 3.8 t ha^{-1}
2.	PE[1]	1X plus	-	-	-	-	Soil temp adjusted to # 1
3.	Bar + PE	1+1	-	-	-	-	PE placed on top of barley residue
4.	None	0	-	-	-	-	Cereal residue removed
5.	Barley	1X	-	+	-	-	Effect of charcoal, vs #1
6.	Barley	1X	-	-	+	-	Effect of fungicide, vs #1
7.	None	0	+	-	-	+	Effect of tillage, vs #4
8.	None	0	-	-	-	-	Effect of roots, vs #4

[1] Wood shavings of *Populous excelsior*.

Table 4.2. Effect of cereal residue, *Populous excelsior* wood shavings (PE), activated charcoal, tillage, and metalaxyl on cucumber emergence and growth.

Residue and rate	Emergence	Plant dry matter yield(35 DAP)		Average soil temp at 2.5 cm
		Total weight	Ave.plant weight	
	No. $plot^{-1}$	g $plot^{-1}$	- g -	- C -
1. Barley (1X)	7.3	20.0	2.7	21.3
2. PE (adjusted)	8.3	32.9	4.1	21.5
3. Bar + PE	6.5	24.2	3.9	21.3
4. No residue no-till	11.5	30.8	2.7	24.8
5. Barley (1X) activated charcoal	8.5	19.1	2.2	21.2
6. Barley (1X) fungicide	7.3	17.7	2.4	21.7
7. No residue tilled	11.0	39.0	3.5	25.0
8. No residue, tillage, or cereal roots	10.5	17.9	1.7	25.9
LSD (P=0.05)	3.4	12.5	0.8	0.7

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CHAPTER FIVE

SPRING-PLANTED CEREALS SUPPRESS WEEDS IN CUCUMBER PRODUCTION

ABSTRACT

The potential of using spring-planted cereals as a weed control strategy in cucumber production was evaluated. Alternatives tested included a stale seedbed with and without cereals sown 2 and 4 weeks before cucumber seeding and cereals sown simultaneous with cucumbers. Including cereals in the systems decreased weed dry matter by 85 percent but had little effect on weed density. Barley planted 4 weeks before cucumber seeding and killed just before cucumber emergence afforded best weed suppression and largest cucumber yield. However, yield of this treatment was 30 percent less than the weed-free check.

INTRODUCTION

Living cereals and cereal residues suppress the germination and growth of small seeded, summer annual weeds (Overland, 1966; Putnam and DeFrank, 1983; Shilling et al, 1986). Cereals and their residues modify the chemical, light, temperature and moisture environment around germinating weed seeds (Barnes et al, 1987; Teasdale et al, 1991). In no-till systems, cereals are fall-planted and spring-killed before crop establishment to provide a mulch (Barnes and Putnam, 1983). An alternative system seeds cereals in the spring 2 to 4 weeks before crop seeding, at the last tillage operation. Researchers at Michigan State University demonstrated that cereal cover crops sown four weeks before cucumber planting and desiccated at crop planting reduced weed competition and increased cucumber yields compared to conventional tillage cucumber production (Dudek et al, 1991). The cereals were desiccated when 15 to 25 cm tall.

Cucumber growers in the Willamette Valley rely primarily on preplant soil preparation, a broadcast application of a broadspectrum herbicide, cultivation and hand labor to control weeds in cucumber production. A stale seedbed system is one preplant strategy utilized to control weeds. Soil preparation is completed 2 to 3 weeks before crop seeding and glyphosate or paraquat is broadcast applied before crop planting or emergence, depending on the herbicide used.

The objective of this experiment was to evaluate the effect of barley (*Hordeum vulgare* 'Galt') and rye (*Secale cereale* 'Wheeler') residues on weed density, weed dry matter yield, and crop growth when planted in a stale seedbed system.

MATERIALS AND METHODS

Soil was cultivated on May 7, 1992, except for final tillage. Treatments were assigned to 1.8 by 3.0 m plots in a randomized complete block design. Spring barley (*Hordeum vulgare* 'Galt') or rye (*Secale cereale* 'Wheeler') seeds were spread with a Gandy fertilizer spreader at 484 seeds m^{-2} on designated cereal planting dates (Table 5.1) along with 220 kg ha^{-1} fertilizer (NPK: 12-29-10) and 3.4 kg ha^{-1} borate (14% boron). A tractor mounted rototiller followed by a roller incorporated the cereal seed and fertilizer into the top 5 cm of soil. All plots were irrigated after the first two cereal planting dates because of an exceptionally dry period during May of 1992.

Glyphosate (1.1 kg ai ha^{-1}) or sethoxydim (0.31 kg ai ha^{-1} with 8 l ha^{-1} COC) were applied to the cereal crops according to treatment schedule with a backpack sprayer and a hand held boom equipped with SS8002 nozzles.

Cucumbers were sown June 5 with a cross-slot planter at a 1.8 m row spacing and 60 kg ha^{-1} fertilizer (NPK:12-29-10) banded next to the row. An additional 120 kg ha^{-1} of urea was sidedressed next to the cucumber row on July 17, before cultivation. Total fertilizer applied during the experiment was 90 kg ha^{-1} of nitrogen, 80 kg ha^{-1} of P_2O_5, 30 kg ha^{-1} of K_2O, and 0.5 kg ha^{-1} of boron.

Two 28 cm diameter samples of cereals and weeds were cut from each plot at cucumber planting and again at herbicide application date to measure weed and cereal dry matter and density. Cereal and weed samples were dried for 4 days at 46 C. Cucumber plants were thinned to a spacing of 13 cm at 17 days after planting (DAP). The 3 m row of cucumbers in each plot was reduced to 1.5 m in length at 38 DAP. Cucumber plants were removed from 0.75 m at either end of the 1.5 m row and weighed to determine the treatment effect on early season crop growth. Weed dry matter and density were assessed on 35 DAP by counting, removing, drying, and weighing weeds taken from two 28 cm diameter areas randomly placed next to the middle of each row but on opposite sides.

The conventionally tilled treatment was maintained weed-free by shallow hoeing and hand weeding, but not cultivated. All plots were hand weeded and cultivated after weed dry matter and density were determined, and kept weed-free from that point. Harvest began on July 28, 53 DAP. Cucumbers were picked 9 times at 3 to 4 day intervals from 1.5 m of row and the fruit weighed and graded.

Data were analyzed using analysis of variance procedures of the general linear model of SAS (SAS Institute, 1986). Treatments were compared using Fishers Protected LSD.

RESULTS AND DISCUSSION

Barley planted 4 weeks before cucumber seeding and killed with glyphosate 4 DAP reduced weed dry matter by 91 percent compared to the same treatment without barley at 35 DAP (Table 5.2, treatments #1 vs #6). On average, the treatments with cereals decreased weed dry matter by 85 percent at 35 DAP[1]. Rye was no more effective than barley in reducing dry matter accumulation. Weed control outcomes were a result of the effect of herbicide, suppression of weeds by the living cereal, and effect of cereal residue. Weed dry matter accumulation determined at herbicide application date demonstrated that the living cereals were very effective at suppressing weeds (Table 5.2).

In contrast, weed density at 35 DAP was constant whether or not cereals were included in the treatment, except for one deviation. Treatment #7 without cereals had nearly twice the weed density of treatment #2 with cereals. It was observed that glyphosate applied 26 days after last tillage in treatment #7 caused complete vegetation kill with very little residue remaining on the surface compared to the companion treatment with cereals (treatment #2) and all other treatments. The soil was nearly bare shortly after cucumber seeding, an excellent environment for germination and establishment of weeds. The cereal residue on treatment #2 may have prevented weed germination through various mechanisms such as soil temperature reduction or allelopathy. Treatments with sethoxydim but without cereal may have responded differently than treatment #7 because this herbicide kills very slowly and did not kill broadleaved weeds, which maintained more soil cover than plots treated with glyphosate.

Cucumber yield within the weed-free control was exceptional (69.5 t ha^{-1}). Yield of treatment #1 was 30 percent less than the weed-free treatment, but still greater than all other treatments. Comparisons between each individual harvest of treatment #1 and the weed-free control revealed that differences between individual harvest weights diminished as the season progressed (Figure 1). On average, cereals reduced cucumber fresh weight accumulation and total yield by 40 and 20 percent respectively, although most of the decrease was caused by treatments with

[1] Single degree of freedom contrast of treatments with cereals vs those without ($P < 0.01$).

sethoxydim[2] (Figure 2). The weed-free control did not represent conventional production conditions; the soil surface was only slightly disturbed to maintain a weed-free surface, and cultivation was absent. A conventional tillage treatment with cultivation was not included in this experiment.

Other than the exceptional growing conditions provided in the weed-free treatment, the factors contributing to the yield reduction in treatment #1 are unclear. It is unlikely weed competition during the 35 days after planting caused the yield reduction; weed dry matter accumulation was minimal in treatment #1. The same held true for treatment #2; the companion treatment without cereal residues (treatment #7) had the same yield even though weed dry matter was substantially more. Plant fresh weights for both treatments at 35 DAP followed a similar trend. Furthermore, there was no difference between cucumber fresh weight at 35 DAP in treatment #1 and the weed-free control, indicating that any damage from the herbicides was insignificant. Perhaps the stale seedbed treatments predisposed cucumbers to some factor that did not affect cucumber growth until later in the season. Alternatively, removing weeds and cultivating at 35 DAP may have negatively affected crop growth. Another hypothesis is that cultivation incorporated cereal residue and weed fresh matter into the soil and caused a short term nitrogen deficiency.

The smallest cucumber yields resulted when cereals were planted 0 to 14 days before cucumber seeding and killed with sethoxydim 21 to 14 days after cucumber seeding, respectively (treatments 3, 4, 5, 8 and 9). Cucumber fresh weight accumulation of treatments #3, #4 and #5 (cereals plus sethoxydim) were substantially lower than the same treatments without cereals, even though weed dry matter accumulation was as much as 10 times greater in the plots without cereal. The cucumbers were impacted more by the cereals than the weeds. In treatment #3, the cereals were near maximum growth while the cucumbers were germinating

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[2] Single degree of freedom contrast of treatments with cereals vs those without ($P<0.01$).

and establishing. The cereals shaded the cucumbers and probably reduced soil temperatures at a critical stage of growth. Treatment #5 replaced barley with rye, and the data suggest that rye was more damaging to the cucumber crop. Rye did not succumb to sethoxydim as quickly as barley; in fact, some of the rye survived until the plots were cultivated.

SUMMARY AND CONCLUSIONS

Barley and rye planted 0, 2, and 4 weeks before cucumber planting and killed with glyphosate or sethoxydim reduced weed dry matter accumulation an average of 85 percent at 35 DAP. Weed density was unaffected, except in one case. The most promising treatment was barley seeded 4 weeks prior to cucumber seeding and the cereal killed with glyphosate just prior to cucumber emergence. In this scenario, barley decreased weed dry matter accumulation by 91 percent.

Cucumber yield was unaffected by the addition of cereals except when the cereal was seeded on the same date as cucumbers and killed 21 days later with sethoxydim. Cereals planted 28 days before cucumber seeding suppressed weeds best and yielded the most cucumbers compared to all other treatments with cereals. However, yield of this treatment was 30 percent less than the weed-free plot. Possible factors causing this yield reduction were the prime growing conditions of the weed-free and uncultivated control, a short term nitrogen deficit, or the 2 to 4 week delay after last tillage for cucumber planting.

Figure 5.1. Yield components of treatment #1 and treatment #10. Treatment #1 was planted with cereals 28 days before cucumber planting and the cereals killed 5 days after cucumber planting. Treatment #10 was kept weed-free.

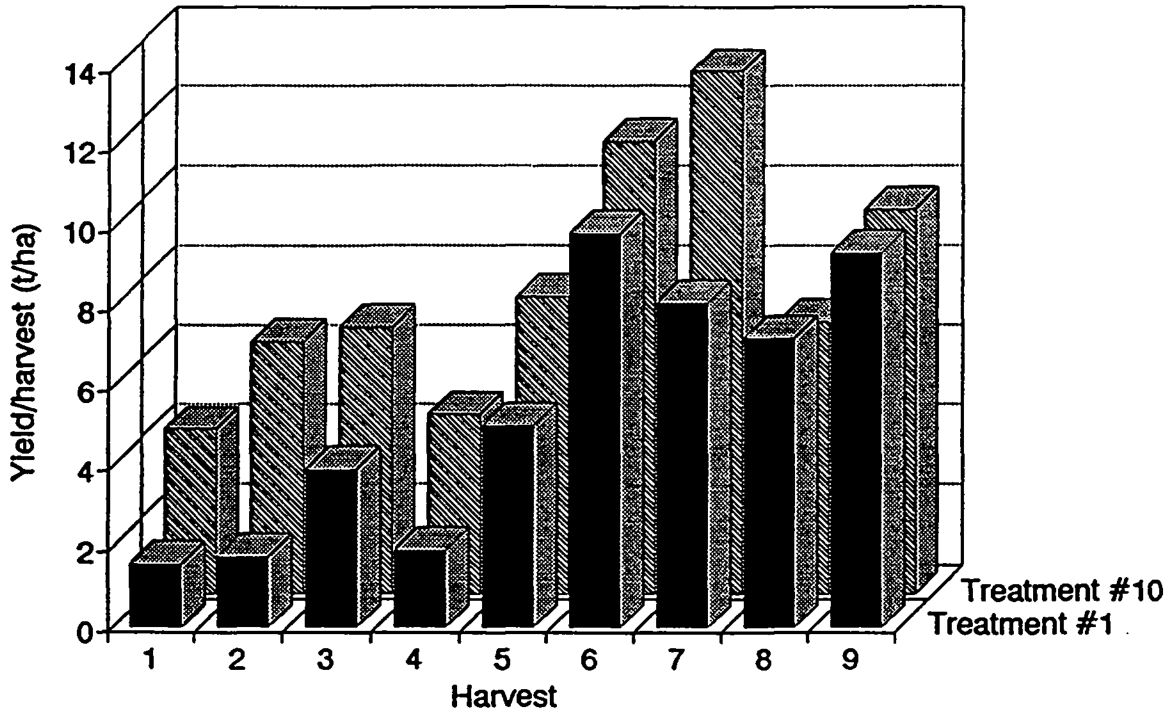
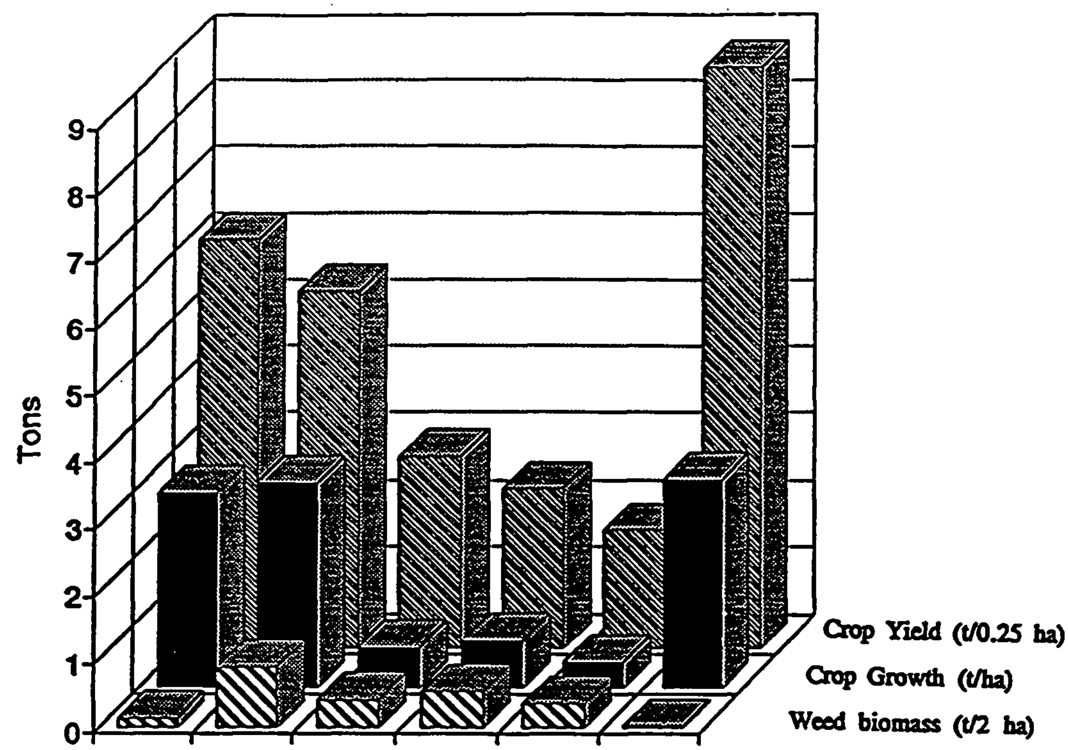


Figure 5.2. Comparison of crop yield, crop growth (35 DAP), and weed dry matter (35 DAP) of treatments with cereals and the weed-free control.



Treatment #	1	2	3	4	5	10
Cereal	barley	barley	barley	barley	rye	none: weed free
Cereal planting date [a]	28	28	14	0	14	-
Cereal kill date [b]	4	-2	12	28	12	-
Herbicide [c]	G	G	S	S	S	-

[a] Days cereal was planted before cucumber planting.
[b] Days herbicide applied after cucumber planting (negative number denotes days before cucumber planting).
[c] G=glyphosate, S=sethoxydim.

Table 5.1. Description and summary of treatments in spring-planted cereal experiment.

	Cereal	Cereal planting date[a]	Herbicide application date[b]	Herbicide	Comments
1.	Barley (var. Galt)	28	4	Glyphosate	Herbicide applied just before cucumber emergence, cereal 20 to 25 cm tall.
2.	Barley "	28	-2	Glyphosate	Herbicide applied 2 days before cucumber seeding.
3.	Barley "	14	12	Sethoxydim	Herbicide applied when cereal 20 to 25 cm tall.
4.	Barley "	0	21	Sethoxydim	Herbicide applied when cereal 20 to 25 cm tall.
5.	Rye (var. Wheeler)	14	12	Sethoxydim	Rye replace barley in treatment #3.
6.	None	28	4	Glyphosate	Control for #1.
7.	None	28	-2	Glyphosate	Control for #2.
8.	None	14	12	Sethoxydim	Control for #3 and #5.
9.	None	0	21	Sethoxydim	Control for #4.
10.	None: weedfree	0	0	-	Plots kept weed free.
11.	None: unweeded	0	0	-	

[a] Cereal planting date and/or last tillage date, and fertilizer application (days before cucumber seeding).
[b] Herbicide application date, days after cucumber seeding. Negative number denotes days before planting

Table 5.2. Effect of spring-planted cereal residues on weed dry matter accumulation and weed density.

Treatment description				Weeds at herbicide application date		Weeds at 35 DAP	
Cereal	Cereal planting date[a]	Date herb. applied[b]	Herb[c]	Dry matter	Density	Dry matter	Density
				- g m^{-2} -	-No.m^{-2}-	-g m^{-2}-	-No. m^{-2} -
1. Barley (var.Galt)	28	4	G	6 b	143 cd	12 d[d]	67
2. Barley "	28	-2	G	9 b	252 bc	81 cd	75
3. Barley "	14	12	S	2 b	57 ef	36 cd	78
4. Barley "	0	21	S	16 b	41 f	48 cd	62
5. Rye (var.wheeler)	14	12	S	6 b	93 de	31 cd	96
6. None	28	4	G	99 a	341 ab	131 bc	66
7. None	28	-2	G	40 a	460 a	244 ab	129
8. None	14	12	S	14 b	67 ef	402 a	73
9. None	0	21	S	18 b	33 f	428 a	65
10.None weedfree	0	0	-	-	-	2 e	4
11.None unweeded	0	0	-	-	-	172 ab	63
LSD (P=.05)				LT[e]	LT	LT	45

[a] Days cereal was seeded before cucumbers were planted (or last tillage).
[b] Days after cucumber seeding that herbicide was applied; a negative number indicates days before cucumber seeding.
[c] Herbicide applied: G=glyphosate, S=sethoxydim.
[d] Values in the same column followed by the same letter are not significantly different (FPLSD, P=0.05).
[e] LT = natural log transformed.

Table 5.3. Effect of spring-planted cereal residues on cucumber growth and yield.

Treatment description				Cucumber growth	Total cucumber harvest (after 9 harvests)	
Cereal	Cereal planting date[a]	Herbicide application date[b]	Herb.[c]	Plant fresh weight 35 DAP	Fruit	Weight
				- g m^{-1} row -	- No. 1.5 m^{-1}	- t ha^{-1} -
1. Barley (var.Galt)	28	4	G	530 ab	254	48.7
2. Barley "	28	-2	G	560 ab	233	42.6
3. Barley "	14	12	S	110 d	127	22.9
4. Barley "	0	21	S	130 d	105	19.1
5. Rye (var.wheeler)	14	12	S	70 d	83	14.0
6. None	28	4	G	410 b	234	47.3
7. None	28	-2	G	720 a	202	40.5
8. None	14	12	S	220 c	100	19.0
9. None	0	21	S	490 ab	199	39.0
10.None weedfree	0	0	-	570 ab	338	69.5
11.None unweeded	0	0	-	470 ab	87	29.0
LSD (P=.05)				LT	57	10.7

[a] Days cereal was seeded before cucumbers were planted (or last tillage).
[b] Days after cucumber seeding that herbicide was applied; a negative number indicates days before cucumber seeding.
[c] Herbicide applied: G=glyphosate, S=sethoxydim.
[d] Values in the same column followed by the same letter are not significantly different (FPLSD, P=0.05).
[e] LT = natural log transformed.

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