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WEED AND VEGETABLE RESPONSE TO ALLELOPATHIC
INFLUENCES IN NO-TILLAGE PLANTINGS

By
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ABSTRACT

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Spring and fall-sown cover crops were evaluated for their ability to reduce weed populations in succeeding vegetable crop plantings. Living sudangrass (Sorghum vulgare Pers.) reduced populations of smooth crabgrass (Digitaria ischaemum (Schreb. Muhl.) and common purslane (Portulaca oleraceae L.) by 45 and 70% respectively. Weed biomass was also greatly reduced by residues of sorghum and sudangrass. In vegetable compatibility trials, stands of tomato and carrot were severely reduced by sorghum residues whereas stands of cabbage and snap beans were increased.

Fall-killed rye (Secale cereale L.) and winter wheat (Triticum aestivum L.) residues provided 70 and 90% weed reduction, respectively, and stimulation of pea growth. In similar studies on a muck soil, conventional tillage increased weed biomass over no-tillage by 130%. Yields of carrots and onions were unaffected by cover crop residues. Allelopathic crop residues

complemented the effects of commercial herbicides in cucumber and snap bean plantings. Rye residues contributed the most to weed reductions.

The toxicity of sorghum shoot extracts was bioassayed in sterile culture to eliminate possible microbial influences. After developing optimum conditions for bioassay sensitivity, the activity of sorghum shoot extracts was shown to increase with plant age. The sterile culture techniques provided an excellent means of confirming allelopathic mechanisms.

Greehouse studies substantiated field observations of crop stimulation and weed suppression with sorghum residues. Enhancement of snap bean growth was provided by residues of both shoots and roots. Stimulation persisted for at least 25 days after sorghum desiccation. Suppression of weeds was sustained for a three week period.

This thesis is dedicated to my parents, Beatrice and Stephen, who have invested their love, thoughts and prayers to sustain me during many trying times.

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INTRODUCTION

In this thesis, I have evaluated the potential of using naturally-occurring plant toxins to obtain a level of weed control in a no-tillage cultural scheme for vegetable production. Many previous workers have identified the ability of one plant to affect the growth of another, but few have attempted to use it.

My ultimate goal is to initiate the kind of thinking which will lead to research efforts designed to reduce energy inputs while preserving the quality of the soil and maintaining a high level of productivity. The time has come and passed when the equilibrating forces of nature can be resisted with an abundance of chemical energy. We can no longer mine the land and expect stability in our agricultural community. Understanding the intricacies of natural ecosystems will aid us in designing environmentally sound cultural techniques which in the long run will encompass the prerequisite of economic feasibility.

CHAPTER 1

GENERAL LITERATURE REVIEW

Introduction.

A great deal of published literature has addressed the subject of interactions between higher plants. The obvious interference mechanism among plants is the competition for specific resources, such as mineral nutrients, water and light. A more subtle interference mechanism involves the release of chemicals into the environment from one plant which can directly or indirectly (through microorganisms) affect the germination and development of another. The term allelopathy has been used by Molisch (32) to describe plant/plant and plant/microorganism interactions which can be either harmful or beneficial. Several reviews (1, 9, 38, 41, 47) and a book (40) have been written which elucidate the ways in which numerous plant species can chemically alter the growth of other plant species.

The literature has, for the most part, dealt with describing the species capable of allelopathic interactions and the chemical agents which are used to elicit a degree of influence. A recent review on the impact of allelopathy in agroecosystems has been presented by Putnam and Duke (38). This review brings to light the possibilities of exploiting the

allelopathic potential of plants for use in the area of weed control, crop stimulation through advantageous plant associations and as sources of new chemistry for chemical pest control. This thesis will focus on the use of allelopathic crop residues as agents of weed suppression in the production of vegetable crops.

Allelopathic aspects of crop residues.

Grain sorghum (Sorghum bicolor) was one of the earliest crops to be recognized as being detrimental to crops which follow it in succession. Ten Eyck (46) in 1907, working with time sequence cropping studies recorded the lowest corn yields when corn followed sorghum compared to other crops. A few years later, Fletcher (17), in Egypt, observed that Sesamum indicum L. could not grow within two feet of a living sorghum plant. In 1921, Vinall (48) recorded yields of oats and winter wheat at an average of 25.4 bu/A after corn and an average of 20.7 bu/A following various sorghums. Soon after, Cole (13) reporting on crop rotations, recorded a 40% drop in wheat yields following sorghum compared to wheat following corn. From 1923 to 1931, several articles were published to elucidate the mechanism of the deleterious after effects of sorghum. Two theories were argued as the cause of the "sorghum soil sickness". One claimed natural toxins released from living plants and decomposing crop residues. The other claimed that

living sorghum exhausted the nutrient resources of the soil which was augmented by microbial activity, stimulated by easily oxidized organic matter from crop residues. A combination of these two theories would seem to be the most likely explanation for the problems observed with crops that followed sorghum. New insight in this respect was provided by Guenzie and McCalla (19, 20, 21). Working with aqueous extracts from several crop residues they were able to isolate and identify phytotoxic phenolic acids. The residues evaluated in their study were oats (Avena sativa L.), wheat (Triticum aestivum L.) and corn (Zea mays L.). Sorghum serves as a model for investigations into the nature and mechanism of phytotoxicity in crop residues. A review by McCalla (29) covers a wide range of crop residues with adverse effects on the following crop.

To develop the use of surface mulches as weed suppressing agents, it is important to understand the nature of toxin release and its persistence in the soil. Hawkins (25) observed that the detrimental effects of sorghum for the most part disappeared in a few months after the crop was harvested. McKinley (30) worked with soil incorporation of corn and sorghum residues to obtain more information of the depressions in yields by sorghum. With wheat as the test species, he found that during the early part of the experiment, sorghum depressed the growth of the wheat more than corn. At

the end of the experiment, treatments with sorghum tops produced increased yields over control with the increases being greater than that caused by corn. Patrick et al. (34) studied the presence of phytotoxic plant compounds in decomposing plant residues, soils with a high content of organic matter and soil in direct contact with plant residues. In bioassays, substances could be found at concentrations active against seedlings of lettuce (Lactuca sativa L.), bean (Phaseolus vulgaris L.), broccoli (Brassica oleracea L.), and tobacco (Nicotiana tabacum L.). Phytotoxicity of extracts on these plant species was worst after residues of barley (Hordeum vulgare L. emend), rye (Secale cereale L.), wheat (Triticum aestivum L.), Sudan grass, vetch (Vicia sativa L.), broad bean (Faba vulgaris Moench.), and broccoli had been decomposing for 10-25 days. Toxicity appeared to diminish as decomposition proceeded. Several extracts were found to be stimulatory after 30 days of decomposition. Guenzie et al. (21) studied the phytotoxicity of aqueous extracts from residues of wheat, oats (Avena fatua L.) and corn (Zea mays L.) and how it changed during decomposition. Extracts made from residues at the time of harvest revealed, in bioassay with wheat seedlings, toxic components in all residues with the following order of toxicity: wheat > oats > corn > sorghum. Eight weeks of exposure to field decomposition removed all water soluble toxins from the

straw of wheat and oats. Corn and sorghum required 22 to 28 weeks of field decomposition to remove all water soluble toxins. Cochran et al. (12) studied the phytotoxicity problems with no-till planting of winter wheat. Mats of lentil (Lens culinaris Medic.), pea (Pisum sativum L.), wheat and winter barley were placed on bare ground. Water extracts of the residues and the soil beneath them were bioassayed weekly with wheat seedlings. All residues produced wheat seedling root inhibitors when conditions became favorable for microbial growth. Toxicity generally followed wet weather and temperatures above freezing, but below 15°C. Lentil and pea straw were most toxic to wheat in fall and early winter, with little or no inhibitors produced later. Wheat and barley demonstrated toxic release during the winter and intermittantly between late winter and early spring.

It is obvious that toxic release from surface residues can be cyclic and very much dependent on environmental conditions such as soil moisture, temperature and microbial activity. It also seems clear that crop residues contain a variety of components, requiring various means for escape into the soil environment. It will be the challenge of the weed scientist to devise a cropping system which coordinates weed seed germination with the toxic release from surface residues while providing for normal crop growth.

Plant residues in no-tillage farming.

The use of no-tillage farming has been increasing since the early 1960s. With increasing awareness of resource conservation, this trend should continue well into the future, as indicated by a recent USDA study. A trend of this type will add greater significance to the choice of cover crop (or surface residue) with respect to overall farm management. Work in no-tillage was initiated in the early 1950s by Barron, Fitzgerald and Sprague (2, 43). Their work indicated that row crops could be successfully grown without tillage, where chemical control of an existing sod is achieved. Since then, research has been initiated to determine the feasibility of no-tillage, its impact on the soil physical condition and on crop growth.

A book written by Phillips and Young (35) on no-tillage provides a practical guide for making this system work in several field crops. Their book contains information on the selection of tillage practices, soil types suitable for no-till, suggestions on crop rotations, the economics of no-till, concluding with machinery and fertilizer recommendations. Blevins (7) has studied alterations of the soil environment in cropping systems using no-tillage seedbed preparation. His work indicated that no-till treatments increased the volumetric moisture in the top 30 cm of the soil horizon. Increases were brought on by reduced evaporational losses and a greater

ability to store soil moisture. Jones (26) studied the importance of a surface mulch in conserving soil moisture. Seedbeds for corn were prepared both by conventional and no-till methods, each with and without a surface mulch. The effects of tillage were considered minor. The data indicated that the surface mulch was the major component of the moisture conserving aspect in no-tillage seedbed preparation. Blevins (8) studied changes in soil physical characteristics in a five year planting of continuous no-till corn at various rates of N applications. He determined that no-tillage with moderate rates of N application most nearly preserved the soil characteristics found under the bluegrass sod present at the beginning of the study.

Knave et al. (27) investigated the effects of tillage systems on performance and elemental absorbance of five vegetables (information on weed control in four vegetables was also included). Cucumber, sweet corn, tomato (Lycopersicon esculentum Mill.) and pepper (Capiscum annum L.) were evaluated under no-till and conventionally tilled conditions. Irrigation water was used to move chemicals into the soil on no-till plots where soil incorporation of a herbicide was recommended. Successful weed control was achieved in all these crops with the use of recommended herbicides. Beste (5) evaluated the effectiveness of several herbicides on three vegetable crops planted no-till. Acceptable weed

control was achieved in tomato, lima beans (Phaseolus lunatus L.) and cucumber with standard herbicide applications. With rye cover crop in no-till plots, yields of tomatoes and lima beans were the same as in conventionally tilled plots, but cucumber yields in no-till plots were significantly reduced. Standifer and Beste (44) reviewed weed control and tillage methods in sweet corn, snap beans, watermelon (Citrullus lanatus (Thunb.) Mansf.), direct seeded tomatoes, lima beans and cucumber. In all crops except cucumber, yields of no-till plots were either equal to or greater than yields on conventionally tilled plots. Weed control was adequate but not equally effective in all crops.

The literature indicated that no-tillage seedbed preparation presents a viable option for commercial vegetable growers. Standifer relates that "most researchers feel that weed control is the dominant problem with limited tillage programs for vegetables." As already noted, commercial herbicides can be used effectively in reduced tillage systems.

The expense and time consuming procedure for permitting the legal use of herbicides on a wide variety of crop plants necessary for vegetable and fruit production has deterred registration and provided growers with very limited options for chemical weed control. Restrictions on the use of chemical weed control in vegetable crops along with the advent of no-tillage

farming has provided a research environment that makes the exploitation of allelopathy for enhanced weed control a timely and worthwhile endeavor.

CHAPTER 2

THE EFFECTS OF SPRING-SOWN COVER CROPS ON THE GROWTH OF WEEDS AND VEGETABLES IN NO-TILLAGE (NT) PLANTINGS

ABSTRACT

Weed densities were recorded 22 days after planting eight cover crops to determine the living crop effect on weed emergence. Densities of common purslane were reduced 75% by sudangrass (Sorghum bicolor L.). Populations of common purslane were reduced 70% by desiccated residues (30 days post-paraquat application) of sudangrass. Residues of sorghum and sudangrass reduced populations of smooth crabgrass by 98% and 99% respectively over control. Total weed weight and weight of individual weed species (60 days post-paraquat application) were consistently reduced with crop residues of: oats < sorghum < sudangrass. A vegetable compatibility study was initiated on a Conover loam to determine performance of seven vegetable crops planted into non-tilled soils with surface residues of four Sorghums and corn. Stands of sweet corn, cucumber, lettuce, and tomato were increased with some residues and reduced by others. Cabbage and snap beans were stimulated while carrots were predominately suppressed.

INTRODUCTION

The presence of spring sown cover crops can aid in weed suppression in two ways. Several crops have been found to have superior interference ability with weeds: hybrids of sorghum (22), rice (Oryza sativa L.) (33) and accessions of oats (Avena fatua L.) (16) and cucumber (Cucumis sativus L.) (37). Cover crops with similar interference ability could reduce weed populations in areas where a NT planting of vegetables was to follow. The mulch provided by these crops, after desiccation, could continually reduce weed populations through the release of phytotoxic compounds (12, 14, 20, 21, 34). Proper management of cover crops in conjunction with no-tillage seedbed preparation could provide a practical means of introducing desirable plant residues into the agroecosystem. The objective of these studies was to evaluate the weed suppressing potentials of several cover crops as living plants and as surface mulches in NT plantings and to ascertain vegetable crop tolerance to these mulches.

MATERIALS AND METHODS

Initial evaluation of spring-sown cover crops for weed control.

Eight cover crops were planted on June 14, 1977 on a Spinks loamy sand. A v-belt Planet Jr. seeder was used to plant the crops to a depth of 2.5 cm. Treatments consisted of six 30 cm wide rows of crops. Total plot size was 3 x 7.6 m. The experimental design was a completely randomized block with four replications. The cover crops were barley (Hordeum vulgare L. 'Wong'), rye (Secale cereale L. 'Rosen'), winter wheat (Triticum aestivum L. 'Genesee'), sorghum ('Bird-A-Boo'), oat (unknown cultivar), sudangrass ('Monarch'), and soybean (Glycine max (L.) Merr. 'Amsoy'). Control plots were not planted.

To determine the effect of living cover crops on various weed species, one 929 cm² quadrat per plot was sampled 22 days after crops were planted. Densities of the predominant weed species were recorded. Thirty days after planting, all plots received a paraquat spray at a rate of 1.1 kg/ha with a nonionic surfactant (X-77)¹ at .1% (v/v). After 30 days, weed densities were again taken to determine the effect of undisturbed crop residues on weed emergence. At 90 days after planting (60

1. X-77 was used in all subsequent paraquat spray applications.

days after paraquat application), weeds were harvested by species from one 929 cm² area per plot and dried at 50-60°C.

Vegetable compatibility with five mulches in a NT planting.

On June 11, 1978, five cover crops were planted with a grain drill on a Conover loam. Seeds were planted to a depth of 2.5 cm in rows 10 cm apart. Total plot size was 3 x 7.6 m. The cover crops planted were: sorghum ('Bird-A-Boo', 'F.S. 24' and 'Milkmaker'), sorghum x sudangrass hyb. ('Haygrazer') and sweet corn (Zea mays L. 'Gold Cup'). No crop was planted in control plots. The experimental design was a split block with main plots of cover crops and subplots of seven vegetable crops. The cover crops were desiccated with a paraquat application at a rate of 2.2 kg/ha, 36 days after planting (July 16). The vegetable crops were planted at recommended depths with a disc-type Planet Jr. mounted on a tool bar behind an Allis Chalmers fluted coulter originally used on a NT corn planted (Figure 1). The crops planted were cabbage (Brassica oleracea L. 'Market Topper'), lettuce (Lactuca sativa L. 'Ithaca'), carrot (Daucus carota L. 'Spartan Delight'), tomato (Lycopersicon esculentum Mill. 'Heinz 1350'), sweet corn ('Gold Cup'), and snap beans (Phaseolus vulgaris L. 'Spartan Arrow').

Since the vegetables were planted rather late in the growing season, all could not provide a commercially

Figure 1. Planet Jr. planter modified for no-tillage planting.



important product as a measure of yield. To maintain a consistent form of measure, fresh weights of the entire plant of all crops were obtained. The vegetables were harvested at various times after planting: tomato, snap bean and sweet corn (57 days), cucumber (61 days) and cabbage (89 days). Yield data were not taken on lettuce and carrots.

RESULTS AND DISCUSSION

Initial evaluation of spring-sown cover crops for weed control.

Several living cover crops altered weed densities 22 days after planting (Table 1). The weed species unaffected were carpet weed (Mollugo verticillata L.) and smooth crabgrass (Digitaria shaemum (Schreb.) Muhl.). None of the living cover crops reduced stands of prostrate pigweed (Amaranthus blitoides S. Wats.), although stands were increased with rye. Populations of common purslane were reduced with soybean < wheat < sorghum < oat < sudangrass.

After application of paraquat, the amount of residue in plots were not determined but appeared to differ for each cover crop. Weed counts taken 30 days after the paraquat spray treatment showed no difference in the appearance of prostrate pigweed and carpet weed. These species were present at such low numbers (one and six respectively in control) that random sampling of each plot could have easily skewed the treatment effects. Crop residues of: soybean, oat, sorghum, and sudangrass reduced stands of common purslane and smooth crabgrass (Table 2). The latter two cover crop species almost completely controlled populations of smooth crabgrass.

The initial analysis of variance (ANOVA) for

weed biomass accumulation did not indicate a significant treatment effect although suppression of weed growth with several mulches was apparent. Inspection of the raw data revealed a non-independent relationship between treatment means and their variance, violating an assumption of the ANOVA (28). Intense suppression and stimulation of weed growth by mulches resulted in a low variance while minimal effectiveness allowed for a wide deviation of weed growth among the replicates of a given treatment. An arcsine transformation of the data allows for a more valid analysis when this type of distribution (binomial) occurs. Raw data converted to percent reduction over control where stimulation of weed growth was assigned a value of 0 with a .99 assigned when no weeds were present.

Consistent reductions in common purslane occurred in mulches of: oat < sorghum < sudangrass, and of smooth crabgrass with: soybean < oat < sorghum < sudangrass. Total weed biomass included several weed species: common purslane, smooth crabgrass, prostrate pigweed, and common lambsquarters (Chenopodium album L.). Reduction in total weed biomass occurred in mulches of: oat < sorghum < sudangrass (Table 3).

Vegetable compatibility with five mulches in a NT planting.

Weed data from the previous year indicated a high degree of weed suppressing activity in the Sorghum family. For that reason, selections from this group were chosen to provide the surface mulch to assess vegetable tolerance. Since Sorghums cannot survive Michigan winters, one possible use could involve spring sowing followed by a NT planting of a short season vegetable.

Stand counts of seven vegetables under six mulches were taken on a 2 m section of row, 25 days after seeding (38 days after cover crop desiccation). The ANOVA for stand counts indicated a significant interaction for the treatment factors of mulches x vegetables, pointing out that the vegetables did not respond in the same way to the mulches (Table 4). The data on stand counts denotes the following:

Cabbage: No reduction in stand counts with any cover crop. Increases over control occurred in all cover crops except 'F.S.24' sorghum.

Carrot: All cover crops except 'F.S.24' sorghum reduced counts.

Corn: 'Milkmaker' sorghum reduced stands, while 'F.S.24' sorghum increased them over control.

Cucumber: 'Milkmaker' and 'F.S.24' sorghums and 'Yieldmaker' sorghum x sudangrass hyb. decreased

counts over control. Increases occurred with 'Bird-A-Boo' sorghum and 'Gold Cup' sweet corn.

Lettuce: 'Bird-A-Boo' sorghum increased counts while 'Milkmaker' sorghum and 'Gold Cup' sweet corn reduced them.

Snap Bean: 'F.S.24' sorghum increased counts with all others showing no effect.

Tomato: Severe reduction in stands occurred with 'Bird-A-Boo' and 'F.S.24' sorghums.

Yields of carrots were not taken due to poor growth in all plots, and deer damage to lettuce prevented worthwhile measurements. Since all crops could not produce commercially important parts, fresh weights of the entire plant for all species were taken to assess growth. Snap beans and cucumbers did produce pods and fruit respectively, but whole plant weights were taken to provide a consistent form of measurement similar to that used with the other crops. Vegetable crop growth was not altered by any of the mulches (Table 5).

CONCLUSION

The use of spring-sown cover crops can be effective in reducing weed populations where residues are not disturbed. The Sorghums appeared to be particularly active in weed suppression, although several vegetable crops appeared unaffected. Rice (40) devotes a chapter of his book on allelopathy to the 'Factors affecting the quantities of inhibitors produced by plants'. Plant stress appears to increase the level of inhibitors produced by plants. Similar conditions imposed upon living plant species may enhance their weed suppressing influence as mulches. It appears that spring-sown cover crops could provide weed control benefits in NT plantings with short season vegetables adaptable to this cultural scheme.

Table 1. Weed counts 22 days after seeding as influenced by living crops. Counts on 929 cm².

Cover Crop	Smooth Crabgrass	Prostrate Pigweed	Common Purslane
Control	47	10	16
Barley	52	8	11
Oat	40	5	9
Rye	49	27	11
Sorghum	51	11	6
Sudangrass	22	7	4
Soybean	34	8	8
Wheat	44	8	9
LSD 5% Level	NS	11	5

Table 2. Weed counts as influenced by cover crop residues (30 days post-parquat desiccation). Counts on a 929 cm² area.

Cover Crop	Common Purslane	Smooth Crabgrass
Control	60	42
Barley	62	50
Oat	21	10
Rye	58	33
Sorghum	26	1
Sudangrass	19	0.2
Soybean	25	9
Wheat	43	32
LSD 5%	30	36

Table 3. Weed dry weight accumulation (expressed as percent reduction over control) as influenced by cover crop residues (60 days post-parquat desiccation). Weeds harvested from one 929 cm² area per plot.

Cover Crop	Common Purslane ^a	Smooth Crabgrass ^a	Total Weeds ^{a,b}
Barley	4	0	0
Oat	71	85	52
Rye	21	15	5
Sorghum	74	99	63
Sudangrass	89	99	64
Soybean	54	74	46
Wheat	37	31	18

LSD 5% 61 71 46

^a Conclusions based on ANOVA of Arcsine transformed data.

^b Species included: prostrate pigweed, common lambsquarter, smooth crabgrass, and common purslane.

Table 4. Stand counts on NT vegetables as influenced by cover crop residues (35 days after desiccation). Measurements obtained from 2 m of row.

Cover Crop	Plant/2 m					
	Cabbage	Carrot	Corn	Cucumber	Lettuce	Snap Bean Tomato
Control	85 ^a	76	63	65	56	36 55
Sorghum:						
'Bird-A-Boo'	105	67	71	87	47	40 69
'Milkmaker'	93	57	56	54	79	36 28
'F.S. 24'	87	76	62	57	52	51 29
Sorghum x Sudangrass:						
'Haygrazer'	100	65	59	48	54	35 52
Sweet Corn:						
'Gold Cup'	100	63	58	85	61	33 68

^a Residue x vegetable interaction significant at the 5% level. LSD at 5% = 4, for all means within a column.

Table 5. Entire crop plant fresh weight (kg/3 m of row) as influenced by cover crop residues.

Cover Crop	kg/3 m			
	Cabbage	Corn	Cucumber	Snap Bean Tomato
Control	5.9 ^a	4.9	8.5	2.9 2.2
Sorghum:				
'Bird-A-Boo'	5.6	4.8	6.9	2.8 2.2
'Milkmaker'	5.0	4.9	12.7	3.8 2.7
'F.S. 24'	6.3	4.9	11.6	4.0 2.6
Sorghum x Sudangrass:				
'Haygrazer'	5.3	4.7	9.7	3.4 2.0
Sweet Corn:				
'Gold Cup'	4.6	5.0	8.9	3.2 3.5

^a Residue x vegetable interaction not significant. Means within a column are not significantly different at the 5% level.

CHAPTER 3

THE INFLUENCE OF FALL-PLANTED COVER CROPS ON WEEDS AND VEGETABLES IN NO-TILLAGE PLANTINGS

ABSTRACT

Fall-planted cover crops were evaluated for their influence upon weeds and peas (Pisum sativum L. 'Perfected Freezer') in no-tillage (NT) plantings over two growing seasons. In the first year, winter-killed barley and oats increased the yield of peas over a no crop control, whereas rye had a detrimental effect on pea growth. Weed densities in this experiment were low and not affected by cover crop treatments. In the second year, treatments included winter-killed species along with winter-hardy species chemically killed in fall or spring. Increased pea yields occurred where oats and fall-killed rye, winter wheat and winter barley preceded the crop. Weed growth, measured by dry weight accumulation, was not clearly affected by the various residues. Excessive variation among treatments with respect to weed distribution may have prevented statistical separation of treatment effects.

Similar cover crops were utilized in experiments with onions and carrots on muck soils. An added factor in this experiment was tillage vs. no-tillage across

all residues. Conventional tillage (CT) increased weed pressure over NT plots by 130%. There was no influence of individual residues on weed pressure or on yield of onions and carrots.

INTRODUCTION

Cochran et al. (12) studied different crop residues as surface mulches and their release of toxins into the soil environment at various times of the year (from early fall to late spring). Environmental factors significant in the appearance of toxins from the residue were precipitation levels, temperature and microbial activity. To exploit the allelopathic potential of surface residues, one must determine the optimum time for desiccation and subsequent release of toxins into the soil. With fall-planted cover crops, this factor becomes crucial in the management decision. The variables of the time of cover crop planting, winter-hardiness of the species and time of cover crop desiccation must be coordinated to elicit the desired response from the surface residue during the growth of the cash crop.

One can postulate on how the choices made on the variables mentioned above can influence the expression of surface residues on succeeding plant species. Beginning with the time of fall-planting: early planting will provide a substantial amount of plant material before growth is essentially stopped by low temperatures. Early planting of winter-killed species may be essential to provide enough plant tissue to elicit a significant impact upon plants in the spring. Winter-hardy species

provide another late fall option of using chemical means of desiccating crops in the late fall or at various times in the spring. With fall-killed treatments, an early planting date takes on the same considerations as when winter-killed species are used (i.e. significant biomass accumulation). With spring-kill treatments, fall planting date may not be as important as time of desiccation. Considerations here involve not only the amount of biomass desired, but how the stage of cover crop growth will affect the subsequent release of compounds into the soil environment. Patrick et al. (34) demonstrated that surface residues vary in their toxicity to crops depending on the duration of leaching and decomposition. The purpose of the following studies was to determine how species and desiccation of cover crops affects succeeding weed and cash crop growth.

MATERIALS AND METHODS

First year evaluation of cover crops in NT peas.

On August 15, 1977, four cover crops were planted with a grain drill to a depth of 2.5 cm in rows 10 cm wide on a Hillsdale sandy loam. Total plot size was 3 m wide and 7.6 m long. Soil samples were taken before the fall planting to determine lime and nutrient requirements for optimum growth. The cover crops planted were rye, spring barley, oat, and winter wheat, all of unknown cultivars. Two plots in each replicate were maintained with no crop. The experimental design was a completely randomized block with four replicates.

On April 18, 1978, all plots except one control per replicate received a glyphosate spray at a rate of 1.1 kg/ha. Peas ('Perfected Freezer') were planted with a disc-type Planet Jr. modified for NT planting. Peas were planted to a depth of 2.5 cm in rows 30 cm wide. Each plot contained four rows of peas 7.6 m long. Pea yields were taken from the middle two rows. Weed counts on one m² of each plot were taken on July 4 (74 days after herbicide spray). Six m of pea row were harvested on July 5 (63 days after harvest). Fresh weight of the shelled peas was used for the assessment of crop growth.

Second year evaluation of cover crops in NT peas.

On August 31, 1978, seven cover crops were planted with a grain drill on a Dryden sandy loam at the Michigan State Research Farm in Clarksville, Michigan. Seeds were planted to a depth of 2.5 cm in rows 10 cm apart. Total plot size was 3 m wide and 7.6 m long. Experimental design was a completely randomized block with four replicates.

The winter-hardy species were: rye ('Balboa' and 'Wheeler'), winter wheat ('Tecumseh') and winter barley ('Norwind'). All were planted at a rate of 134 kg/ha. The winter-killed crop species were: sorghum x sudangrass hyb. ('Haygrazer'), sudangrass ('Monarch'), grain sorghum ('Bird-A-Boo'), and oat ('Gary Seed'). The sorghums were planted at a rate of 84 kg/ha and oat at 226 kg/ha. Two plots without crops were used as controls for the residue effect. One of these plots received rotary tillage in the spring (May 8) while the other remained untilled. Of the two winter-hardy cover crop species in each replicate, one received a fall application of glyphosate at 1.1 kg/ha while the other received a spring application. The fall applications were made on October 10, 1978. Spring applications, which all plots received, were made on May 8, 1979. A broadcast application of fertilizer (6-24-24 at a rate of 230 kg/ha) was made on May 16. Peas ('Perfected Freezer') were planted with a 'Moore Uni-Drill' (Figure

2) on May 18 at a seeding rate of 140 kg/ha. Two m² areas of pea vines were randomly selected for harvest from each plot. Pea numbers and fresh weight of shelled peas were taken as measure of yield. Two m² weeds were also harvested on the same day (55 days after pea planting) for assessment of biomass accumulation.

Evaluation of fall-planted cover crops in NT muck vegetables.

On August 17, 1978, seven cover crops were planted with a grain drill on a Houghton muck soil. Crops were planted to a depth of 2.5 cm in rows 10 cm wide. These main plots in each replication (3 x 15.2 m) were split by a conventional tillage operation. Winter-hardy cover crop species were planted in two plots in each of the three replicates. The winter-hardy species were: rye ('Norwind' and unknown cultivar), winter wheat ('Genesee') and winter barley ('Norwind' and unknown). Winter-killed species were: sorghum x sudangrass hyb. ('Haygrazer'), sudangrass ('Monarch'), grain sorghum ('Hondo') and oat ('Mariner'). Winter-hardy species were planted at a rate of 134 kg/ha. The sorghums were planted at a rate of 84 kg/ha and oats at 226 kg/ha. Plots with no crop were used as controls.

Of the two winter-hardy cover crop plots in each replicate, one received a fall application (October 10)

Figure 2. Moore Uni-Drill.



of glyphosate at 1.1 kg/ha while all other plots received a spring application (May 5, 1979). A conventional tillage operation thoroughly incorporated residues into the plot layer. Onion ('Spartan Banner') and carrot ('Spartan Delight') were planted with a 'Moore Uni-Drill' on June 11. The seeding rate for carrots was 82 seeds/m and 38 seeds/m for onions. Each plot contained 3 rows of onions and 3 rows of carrots 30 cm apart. The middle row for each crop was used for measurement of yield. On July 16, weeds were harvested on a m² area from each plot for an estimate of dry weight accumulation. Subsequent weed control was maintained in the NT plots by two hand weedings and three applications of nitrofen at 3.4 kg/ha. On October 5, a 4.5 m section of solid crop row for both carrots and onions was harvested. Carrot tops were mechanically removed and fresh weight of roots taken. Onions had not produced commercially sized bulbs, so fresh weight of the entire plant was taken to assess plant growth.

RESULTS AND DISCUSSION

First year evaluation of fall-planted cover crops in NT peas.

The fresh weights of shelled peas were significantly increased where residues of oats and spring barley were present as compared to rye and winter wheat where they did not differ from controls (Table 1). The low yield in control plots may have resulted from interference by weeds, although counts of total weed numbers present were not significantly different. In rye residues, low yields of peas were not due to weed pressure but rather to an obvious reduction in vigor due to the presence of the mulch. The peas growing in the oat plots appeared more vigorous than those in rye plots and this was reflected in yield. Weed growth was not severe in any of the residue plots.

Second year evaluation of fall-planted cover crops in NT peas.

Cover crops of the Sorghums and oats were killed by frost on October 12 and November 30, respectively. The amount of sorghum residue present in the spring was much less than that of oats. Sorghums will need an earlier planting date to allow for more biomass accumulation before killing temperatures occur in the fall. With a greater amount of plant material present, the

impact on plants sown in the spring may be more pronounced.

Both weeds and peas showed a stimulation of growth in oat plots (Table 2). In all cases, plots containing fall-killed cover crops yielded more peas than those with spring-killed cover crops. Spring-killed rye, particularly 'Balboa', was extremely detrimental to pea growth. This observation had also been made in the previous year's evaluation. Weed numbers in these plots were again fairly light and probably did not affect yield responses. Even where weeds were apparently stimulated in oats, pea yields were still greater than in the no crop control (Table 2).

An odd pattern of weed growth was present at the site of this experiment. A strip of approximately two plots wide and across all four replications produced high values of weed biomass for the treatments enclosed in that strip. This added tremendously to the coefficient of variation and resulted in poor separation of treatment effects. The inflated LSD value due to this variation allows for few conclusions based on that difference. As mentioned earlier, weed pressure was fairly light in all plots, except those in the strip. Spring-killed cover crops did appear to have more weeds than fall-killed crops. This may be partly due to increased moisture levels under those mulches, and the

lack of microbial activity to release toxins since the spring was unusually dry.

Evaluation of fall-planted cover crops in NT muck land vegetables.

The greatest difference in weed pressure was demonstrated between methods of seedbed preparation (Table 3). CT plots increased weed pressure on the average of a 130% over NT plots. This demonstrates how tillage brings many more weeds to the surface where conditions for germination are present. The interaction of seedbed preparation (CT and NT) x residues was not significant. This means that the percent reduction in weed control in the NT plots compared to the CT plots was approximately the same for all residues. Weed pressure in NT plots may have been inadvertently increased by application of fertilizer with a drill-type spreader. This operation severely disturbed the residues, after which more weeds germinated in the NT plots. The author feels that without the confounding of weed pressure, brought on by the action of the fertilizer drill, a more accurate and significant measure of weed biomass accumulation could have been taken. The yields of onion and carrot were only taken in the NT plots, since weed pressure was so heavy in CT plots that weeds could not be removed without also seriously disrupting crop plants. Yields of onions and carrots were not affected

by the various residues (Table 4). Rye did appear to depress the growth of onions early in the growing season but this influence was not carried through to harvest.

CONCLUSION

The results on peas indicated how the time of desiccation (either by winter-kill or chemical means) can have a significant impact on growth and subsequent yield. Stimulation in crops has previously been associated with residues in the soil environment that are initially toxic, but become stimulatory by harvest (10, 14, 15). An explanation for the difference in fall and spring-kill desiccation treatments on pea growth may be that toxins present in fall-killed crops are either absent or at a stimulatory level in the spring. Spring-killed crops may release compounds at levels that become detrimental to peas, reducing their yields. A similar explanation may apply to a crop like oats, where in a fall planting it provides stimulation to the spring-sown cash crop, but when spring planted it may prove to be detrimental. These observations indicate that one must carefully manage cover crops to prevent detrimental influence on a succeeding crop plant.

Weed data from the residue treatments were not conclusive due to variability and experimental error. There did, however, seem to be a trend in weed response to various forms of surface residue. Where suppression was minimal, weed density and biomass was highly variable among those treatments. Where suppression was strong, variability was reduced.

On muck soils, the need for more work on NT planting methods is clear. The weed pressure brought on by CT over NT was shown here to increase be 130%. Common problems on muck soils are crop losses by wind blow-out and soil losses by severe water and wind erosion and oxidation. All of these problems could probably be reduced by some degree through the use of NT planting methods. Fall-planted cover crops can offer more options with regard to residue management in long and short seasoned vegetable crops. Their usefulness in crop production is limited only by our skill in management and our imagination in their application.

Table 1. Fresh weight of shelled peas, and weed densities as influenced by fall-planted cover crop residues.

Cover Crop	Shelled Pea Yield (g) ^a	Weeds/929 cm ² b
No crop, spring glyphosate spray	787	18
No crop, without spring glyphosate spray	631	13
Oat	1161	13
Rye	682	6
Spring Barley	1048	9
Winter Wheat	904	14

LSD 5% 314

NS

^a Pea harvest from 6 m of row.

^b Counts made 77 days after glyphosate spray. Weed species included: mouseear chickweed (Cerastium vulgatum L.), yellow foxtail (Setaria lutescens (Weigel) Hubb.) and ladysthumb smartweed (Polygonum persicaria L.).

Table 2. Fresh weight of shelled peas, pea number and total weed dry weight as influenced by fall and spring-killed cover crop residues.

Cover Crop	Time of Desiccation	Pea Stand /2m ²	Shelled Peas /2m ²	Weed Wt /2m ²
No Crop	-	97	379	69
Sorghum x Sudangrass hyb.	Fall frost	91	405	44
Sudangrass	Fall frost	93	387	76
Grain Sorghum	Fall frost	106	447	46
Oat	Fall frost	119	655	121
Rye ('Balboa')	Fall kill	115	706	43
Rye ('Balboa')	Spring kill	78	291	34
Rye ('Wheeler')	Fall kill	100	832	21
Rye ('Wheeler')	Spring kill	93	490	80
Winter Wheat	Fall kill	119	1040	8
Winter Wheat	Spring kill	70	417	14
Winter Barley	Fall kill	114	794	40
Winter Barley	Spring kill	96	559	73
No Crop (rotary tillage)	-	83	420	57
LSD 5%				27
				226
				62

Table 3. Total weed dry weight as influenced by tillage (no-tillage (NT) vs conventional tillage (CT)) and cover crop residues on a Houghton muck soil.

Cover Crop	Time of Desiccation	Tillage Effect		Residue Effect
		CT	NT	
		Dry wt (g/m ²)		Reduction (NT vs CT) in Dry wt (%)
No Crop	-	104	81	27
Sorghum x Sudangrass hyb.	Fall frost	113	31	73
Sudangrass	Fall frost	81	78	3
Grain Sorghum	Fall frost	103	54	48
Oat	Fall frost	96	47	51
Rye ('Balboa')	Fall kill	95	46	51
Rye ('Balboa')	Spring kill	107	31	71
Rye ('Wheeler')	Fall kill	110	63	43
Rye ('Wheeler')	Spring kill	111	28	75
Winter Wheat	Fall kill	92	20	78
Winter Wheat	Spring kill	119	13	89
Winter Barley	Fall kill	121	45	62
Winter Barley	Spring kill	93	28	70
Mean		87	38	56
LSD 5%		20 ^b		NS ^a

^a Interaction for tillage x residue regime not significant at the 5% level.

^b LSD for means of NT vs CT.

Table 4. The yield of onions (fresh wt. of entire plant) and carrots (root wt.) as influenced by cover crop residues.

Cover Crop	Time of Desiccation	Carrots (kg/4.5 m of row) ^a	Onions (kg/4.5 m of row) ^a
No Crop	-	11	16
Sorghum x Sudangrass hyb.	Fall frost	10	17
Sudangrass	Fall frost	10	17
Grain Sorghum	Fall frost	11	18
Oat	Fall frost	12	20
Rye	Fall kill	14	25
Rye	Spring kill	12	22
Winter Barley (unknown var.)	Fall kill	13	20
Winter Barley (unknown var.)	Spring kill	11	15
Winter Wheat	Fall kill	11	19
Winter Wheat	Spring kill	15	22
Winter Barley ('Norwind')	Fall kill	10	19
Winter Barley ('Norwind')	Spring kill	14	25
LSD 5%		NS	NS

^a Means within columns do not differ by ANOVA at 5% level.

CHAPTER 4

THE INTEGRATED USE OF COMMERICAL HERBICIDES AND WEED SUPPRESSING PLANT RESIDUES IN NO-TILLAGE VEGETABLE PRODUCTION

ABSTRACT

The ability of surface residues to complement the activity of herbicides was evaluated in no-tillage (NT) plantings of pickling cucumbers and snap beans on a mineral soil and for carrots on a muck soil. Using fall-planted cover crops, the reduction in weed pressure obtained with herbicides was the same in all residue regimes. Weed pressure was generally less in NT plots compared to conventionally tilled plots. In another experiment with snap beans, a dramatic stimulation of plant growth was observed in NT plots where spring-planted sorghum provided the mulch. Weed pressure in this experiment was negligible. In NT cucumbers, the percent reduction in weed pressure with the herbicide was the same with all residues, but absolute levels of weed pressure were reduced in NT plots. Linuron, in pre and postemergent applications, was evaluated in carrots on conventionally tilled (CT) and NT plots on a muck soil. Spring-grown Sorghum provided the surface mulch in NT plots. The preemergent herbicide application

resulted in a lower level of weed pressure in NT plots. The CT plots proved to be in greater need of postemergent application of linuron to reach the same level of weed control as that obtained in the NT plots. Severe weed pressure in the CT plots weakened the carrots to the extent that they could not survive the postemergent application of the herbicide.

INTRODUCTION

Herbicides have been used in vegetable crops with varying degrees of effectiveness. Knavel et al. (27), studying tillage practices (CT vs NT) on vegetable growth and nutrient uptake, reviewed the weed control obtained in several crops. In cucumber, bensulide was irrigated into the soil on NT plots. Weed control in this crop was more effective when dry weather followed herbicide applications. Atrazine provided excellent residual activity in NT plots of corn, allowing plants to grow rapidly and shade-out competing weeds. Diphenamid used in NT peppers and tomatoes lacked residual activity and allowed broadleaf weeds and grasses to compete with these long season crops. Beste (5, 6) evaluated standard herbicides in NT plantings of cucumber, tomato and lima beans. Standard herbicide treatments provided acceptable weed control in all crops. Bennett et al. (3) evaluated NT plantings of potatoes in desiccated sods of oats and rye. Pre-emergent herbicides were able to provide adequate control of annual grasses in these plots. Standifer et al. (44) reported that successful weed control using commercial herbicides are available in central Washington for limited tillage of asparagus, carrots, potato and sweet corn. Putnam (36) evaluated a zero-tillage cultural system for asparagus. He found that simazine,

monuron and terbacil provided excellent weed control for three growing seasons without injury to asparagus. These reports demonstrate that adequate weed control can be obtained with commercial herbicides in NT plantings of several crops.

Due to expense of labeling herbicides for individual crops, there is a real shortage of chemical control measures which can legally be used in many vegetable crops. It is clear then, that any cultural practice which can reduce weed pressure and be economically implemented must be fully evaluated. The objective of the following studies was to determine if chemical weed control could be enhanced in no-tillage plots if residues with weed-suppressing potential were present.

MATERIALS AND METHODS

Preemergent herbicides in NT plantings of snap beans and cucumbers.

On September 30, 1978, three cover crops (winter wheat ('Tecumseh'), winter barley ('Norwind') and rye ('Wheeler')) were planted with a grain drill on a Con-over loam. The seeds were planted to a depth of 2.5 cm in rows 10 cm apart. The total size of the cover crop plots were 3.0 m wide and 15.6 m long. Two plots of each cover crop were planted in each replicate and four plots with no crop were designated for appropriate controls. All cover crops were planted at a rate of 138 kg/ha. On May 11, glyphosate was applied over the entire experiment at a rate of 1.1 kg/ha. Two of the non-cropped controls were thoroughly disked on May 15. These plots were considered as receiving a standard field preparation for the planting of snap beans and cucumber. Vegetable crops were planted no-tillage in all other plots.

On June 11, snap beans ('Spartan Arrow') and cucumbers ('National Pickling') were planted in half of the 3 x 15.2 m plots to form smaller plots 3 x 6 m in size. Both crops were planted with the 'Moore Uni-Drill', beans at a rate of 100 kg/ha and cucumbers at a rate of 13 kg/ha. On June 16, paraquat was sprayed over the entire experiment at a rate of 1.7 kg/ha. On June 17,

preemergent applications of herbicide were made and irrigated in with 2.5 cm of water. Trifluralin was applied on snap beans at rates of 0 and 0.8 kg/ha, while bensulide and naptalam were applied to cucumbers in combination at rates of (0 and 0) and (4.5 and 4.5) kg/ha. Six m of solid row of bean pods were harvested on August 3 and used to assess crop growth. A m^2 of weeds were also harvested by species from each plot on the same date to estimate their dry matter accumulation. The entire area (18 m^2) of cucumbers was harvested on August 10. The fruits were graded as pickles to assess yield in terms of dollar value. A m^2 of weeds was harvested by species on the same date to measure dry matter accumulation. The response of crops and the weeds were analyzed separately as a 2 way factorial (treatment design) with treatments arranged as a completely randomized block.

The growth of snap beans in response to two surface mulches and trifluralin.

On June 28, 1978, the Conover loam soil was plowed, disked and fertilized (340 kg/ha of 10-24-24). On June 30, 1978, sorghum ('Bird-A-Boo') and sorghum x sudan-grass hyb. ('Haygrazer') were planted to a depth of 2.5 cm in rows 10 cm apart with a grain drill. The strips of cover crops were 1.8 m wide and 12 m long. Strips of no crop were used as controls for the residue effect.

The cover crops grew for 30 days at which time the entire experiment was sprayed with paraquat at a rate of 1 kg/ha. On August 4, snap beans ('Spartan Arrow') were planted with a disc-type Planet Jr. modified for no-till plantings. Trifluralin (0.8 kg/ha) was applied on half of the plots within three types of residue regimes, the experimental design was a split block. On September 23, 100 bean plants were harvested from each plot and fresh weights of the entire plants were used to assess growth.

Comparison of herbicide activity in muck-grown carrots under NT and CT.

On May 22, 1978, sorghum ('Bird-A-Boo') was planted with a grain drill on a Houghton muck soil. Seeds were planted to a depth of 2.5 cm in rows 10 cm apart. The strips of sorghum were 3 m wide and 15.2 m long. Strips with no cover crop were used as controls for the residual effect. On June 6, frost killed the sorghum which was then replanted on June 26. On July 27, the entire experiment received a paraquat spray at a rate of 1.7 kg/ha. The tillage plots were plowed and fitted in the usual manner for planting carrots. Carrots ('Spartan Delight') were planted on July 31 into the two residue regimes with a disc-type Planet Jr., modified for NT planting. The tillage blocks were split by two levels of linuron application (0 and 2.1 kg/ha). The

experimental design was a split block with 5 replicates. Experimental units consisted of plots 3 m wide and 7.6 m long with 3 rows of carrots 30 cm apart.

On August 14, (15 days after herbicide treatment) weed counts on two 929 cm² quadrats were made on all plots. On August 21, plots which did not receive a herbicide application were hand weeded. On August 22, a postemergence application of linuron was made at a rate of 1.5 kg/ha. Weed counts of one m² were taken in all plots on September 11 (21 days after the post-emergent herbicide application). No data were obtained on carrot response to tillage, residue or herbicide application because of late planting date and poor stand.

RESULTS AND DISCUSSION

Preemergent herbicides in NT plantings of snap beans and cucumbers.

A two-way factorial treatment design was used to measure the response of weeds and vegetables to the herbicides and residue regimes. A significant interaction of these factors indicated that the response to the herbicide was not the same in all residue regimes. The response of weeds to these factors is presented in two ways. The degree of weed control refers to the percent reduction in weed pressure when comparing different levels of a single factor (e.g. plots with no herbicide compared to plots which received a chemical treatment). The level of weed control refers to the dry weight accumulation of weed biomass for individual treatments. In plots with cucumber, the degree of weed control obtained with herbicide application was not different among the various residue regimes (Table 1). The level of weed control in NT plots where winter wheat, winter barley and rye were present were significantly lower than in no-crop controls of NT and CT plots. A similar response of weeds was recorded in snap bean plots. Here, the degree of weed control obtained with the herbicide application did not differ among the various residue regimes. The level of weed control in all the NT plots was significantly less than in the CT plots (Table 3). Only residues of rye reduced weed levels below the NT

control. In NT plots where residues, especially rye, were present, there were fewer weeds which required control than in CT plots. The advantage of using crop residues in NT plots is not enhanced herbicidal activity, but rather a reduced level of weed pressure requiring control. Yields of cucumber (Table 2) were not affected by herbicide application or residue regime. Snap beans were also not affected by herbicide application, but increases in yield over CT plots were obtained in NT plots of winter barley and NT control (Table 4).

The growth of snap beans in response to two surface mulches and trifluralin.

Weed population data are not presented because very few weeds were present in all plots. Bean weight was not affected by application of trifluralin. The exceptional observation in this experiment was the stimulation in fresh bean plant weight in response to the various surface mulches. Snap beans planted NT into mulches of sorghum x sudangrass hybrid increased 80 and 112 percent respectively (Table 5). The causes for this response are not understood. It seems unlikely that alterations in the physical characteristics of the soil were sufficient to elicit this response. Stimulation of legumes in response to sorghum residues has also been reported by Conrade (15). His work

investigated the use of fertilizer to minimize the deleterious effects imposed by sorghum. In field studies, legumes grown after sorghum were higher than in plots preceded by fallow. He concluded that the best way to avoid the detrimental after-effect of sorghum is to follow it with a succeeding legume crop.

Comparison of herbicide activity in muck-grown carrots under NT and CT.

Weed counts on two 929 cm² areas over each plot were used to estimate the effect of the preemergent application of linuron in both planting methods (15 days after spraying). Weed counts on one m² in each plot were used to estimate the effect of linuron as a postemergent spray in the two methods of planting (21 days after spraying). Common purslane was by far the most dominant weed species throughout the course of the experiment. Discussion on weed pressure control reflects primarily the response of that weed. Other species that appeared in small numbers during the post-emergence evaluation were: large crabgrass (Digitaria sanguinalis (L.) Scop.), witchgrass (Panicum capillare L.) and stinkgrass (Eragrostis cilianensis (All.) Lutati.). For the preemergent evaluation, the degree of weed control in NT and CT plots were not significantly different (77 and 49 percent reduction in weed pressure with herbicide application). The level of weed control

in the NT plots was 78 percent less than in CT plots (Table 6). Plots where no chemical was applied were hand weeded 21 days after the preemergent linuron spray. Residues in the NT plots received a minimum of disturbance by the hand weeding. Weed counts, taken 21 days after this postemergent linuron application, indicated similar weed control in both NT and CT plots. The degree of weed control needed to reach this level was much greater in the CT plots than in the NT plots. Inspection of the treatment means is essential to appreciate this result (Table 7).

CONCLUSION

These experiments indicate that herbicides can be extremely effective on no-till plots. The advantage of using residues in no-till plots is not the enhancement of herbicide activity, but rather a reduced level of weed pressure requiring control measures. Residual weed control may be possible in areas with a long growing season where the amount of biomass provided by a cover crop is increased when the cash crop planting date can be delayed in the spring. Spring-planted cover crops of the Sorghums may provide a viable option for use in the later planting of legume crops, such as snap beans or sweet peas. On muck soils, the increase in the level of weed pressure brought on by CT is clearly demonstrated. The most severe weed pressure in NT plots of muck-grown carrots occurred where the planting coulter disturbed the soil. Banded application of pre-emergent herbicides may be all that is required for adequate weed control until postemergent herbicides are applied. Refinement of this practice may lead to reduced amounts of preemergent herbicides thus making the use of no-tillage planting methods more economically feasible. Realizing that levels of weed pressure can be reduced by certain cover crops, in no-till plantings, better decisions can be made in choosing the most suitable cover crop to be used in a specific cash crop planting.

Table 1. Weed biomass (dry wt.) accumulation in no-tillage (NT) cucumbers as influenced by preemergent herbicides and cover crop residues.

Cover Crop Regime	Weed Biomass (g/m ²)		% Reduction with Herbicide	Cover Crop Means (g/m ²)
	(-) Herbicide	(+) Herbicide		
No Crop (NT)	252	94	62	173
No Crop (CT)	349	85	75	217
Winter Wheat	157	39	75	98
Winter Barley	131	49	62	90
Rye	102	7	43	54

Mean	198	55	62	--
LSD 5%		42	NS ^a	66

^a Herbicide x residue interaction not significant at 5%.

Table 2. Cucumber yields as influenced by preemergence herbicides and cover crop residues.

Cover Crop Regime	(-) Herbicide	Yield ^a (+) Herbicide	Mean
No Crop (NT)	716.6	827.7	772.1
No Crop (CT)	b	-	-
Winter Wheat	744.4	1011.0	887.7
Winter Barley	1011.0	833.0	922.1
Rye	666.6	933.3	799.9

Mean	784.7	901.2	-
LSD 5%		NS	NS

^a Prices quoted on pickle grades from Green Bay Foods, Eaton Rapids, MI.
August 29, 1979. Value of standard pickle grades:

#1	-	\$4.26/kg
#2	-	\$0.13/kg
#3	-	\$0.09/kg
#4	-	\$0.02/kg

^b No yields recorded because of planting error.

Table 3. Weed biomass accumulation in NT snap beans as influenced by preemergent herbicides and cover crop residues.

Cover Crop Regime	Weed Biomass (g/m ²)		% Reduction with Herbicide	Mean (g/m ²)
	(-) Herbicide	(+) Herbicide		
No Crop (NT)	75	24	68	48
No Crop (CT)	108	79	27	94
Winter Wheat	53	27	51	40
Winter Barley	56	36	36	45
Rye	21	11	48	16

Means 62 35 44 --

LSD 5% 19 NS^a 29

^a The residue regime x herbicide interaction not significant at 5%.

Table 4. Yield of snap bean pods as influenced by cover crop residues.

Cover Crop Regime	(kg/4.5 of solid row)
No Crop (NT)	3.0
No Crop (CT)	2.1
Winter Wheat	2.6
Winter Barley	2.9
Rye	2.4
LSD 5%	0.5

Table 5. Fresh weight of 100 snap bean plants as influenced by mulches of sorghum ('Bird-A-Boo') and sorghum x sudangrass hyb. ('Haygrazer') in NT plantings.

Residue Regime	Fresh wt. of 100 plants (kg)
No Crop	3.2
Sorghum	5.8
Sorghum x Sudangrass	6.8
LSD 5%	1.2

Table 6. Common purslane densities as influenced by preemergent application of the herbicide linuron and method of seedbed preparation (CT or NT).

Method of Seedbed Preparation	Herbicide Application	Density ² b no/929 cm ²	Tillage Means	Herbicide Means
Conventional	-	161		(+) 46
Conventional	+	81	121	
No-tillage	-	42		
No-tillage	+	10	26	
				(-) 102

LSD 5% NS^a

24

^a Planting methods x herbicide interaction not significant (i.e degree of weed control is same in both planting methods).

^b Counts taken 15 days after preemergent application of herbicide.

Table 7. Densities of common purslane as influenced by postemergent applications of the herbicide linuron and method of seedbed preparation.

Method of Seedbed Preparation	Herbicide Application	Counts on m ² a
Conventional	+	247
Conventional	-	4
No-tillage	+	31
No-tillage	-	2

^a Planting method x herbicide interaction significant at 5%. Counts taken 20 days after postemergence application of the herbicide.

CHAPTER 5

ALLELOPATHIC ACTIVITY OF SORGHUM

RESIDUES AND EXTRACTS

ABSTRACT

Extracts of sorghum shoots, for use in sterile bioassays, were made by soaking 1 g of dried tissue in 100 ml of water. Autoclaving did not reduce extract toxicity. Maximim growth and sensitivity to plant extracts was obtained when the sterile growing medium was made-up with .01 M potassium phosphate buffer, whereas nutrient solution reduced the toxicity. Extracts made from sorghum at various stages of development showed a trend toward increased toxicity with increased age.

The stimulation of bean plants with sorghum plant residues was studied over three successive plantings. Residues which provided stimulation in the first and second planting lost their effectiveness in the third planting. The effects of sorghum residues as a surface mulch or when incorporated into the soil were evaluated on both a Houghton muck and a Dryden sandy loam soil. As a surface mulch on a muck soil, sorghum suppressed total weed growth and when incorporated, provided for a slight increase in weed growth. The same

pattern was found on the sandy loam soil with the first weed harvest. The second weed harvest revealed that sorghum could stimulate weed growth both as a surface mulch and when incorporated into the soil.

INTRODUCTION

The question of whether sorghum toxins are directly leached from surface residues or are released during the process of decomposition has been considered in the literature. Breazeale (10) studied the deleterious effects of decomposing sorghum residues by growing test plants on perforated aluminum disks which floated in a test solution. Wheat seedlings developed injury symptoms as sorghum decomposition began. As decomposition continued over several days, seedlings which survived initial toxicity recovered and grew normally. These results indicated that when toxins were released, they were eventually inactivated by microbe activity. Guenzi and McCalla (19) reported on their findings of water soluble toxins leached from sorghum and other residues. Initial studies indicated that salts and reducing sugars did not contribute to the toxicity of water extracts of sorghum residues. Subsequent work eventually lead to the isolation and identification of several phenolic acids in 80% ethanol extracts of sorghum and other residues, which proved to be toxic to test plants (21). Their rigorous extraction and hydrolysis procedure examined the total amounts of phenolic acids present in plant residues. Their work did not completely answer the question of water soluble toxins present in freshly harvested tissue. They did provide insight as

to what toxins may be released in varying amounts upon decomposition. Chou and Chung (11) studied the allelopathic potential of Miscanthus floridulus, a wild mountainous grass species. Simulated rainfall leachates of leaf tissue were studied for their effect on lettuce and for isolation of the compounds responsible for the toxic activity. They identified seven phytotoxic compounds, the first five of which are the same as those reported by Guenzi and McCalla (21). The compounds identified in Miscanthus leaf leachates were: ferulic, cis and trans p-coumaric, vanillic, syringic, p-hydroxybenzoic, (0-hydroxypheny) acetic acid, and an unknown. These last two accounted for 70% of the aqueous extract toxicity. The unknown was thought to be a non-phenolic. The agents of allelopathic expression in wild species appears to share a common strategy with domesticated crop plants.

Soil microbes play an obvious role in the allelopathic expression of plant residues where decomposition is required for a toxic release. There is also the possibility that toxins leached from plant tissues are active against other plants without microbial interaction. The growing of plants in sterile agar allows for investigations of responses to natural toxins in the absence of microbial activity. Melrod (31) in his M.S. thesis demonstrated the usefulness and acceptability of using sterile agar as a growing medium to

assay a variety of plant growth-altering compounds. Earlier work by Schreiner et al. (41) made use of non-sterile agar to study root exudates of wheat seedlings. Sorghum residues as a surface mulch have provided both suppression of weeds and a dramatic stimulation of snap bean growth (Chapters 2, 4). Numerous other papers substantiate the claim that surface residues can affect plant growth through the release of naturally occurring compounds. This investigation examines several factors which influence the toxicity or stimulation from sorghum extracts and residues.

MATERIALS AND METHODS

Investigation of sorghum shoot extracts in sterile media.

Preparation of agar and experimental units.

In all studies, agar preparation and plant growth conditions were based on methods used by Melrod (31). Difco-Bacto agar was mixed in various types of aqueous solutions. Fifteen grams of agar were mixed with the aqueous solution and heated to boiling. A repipeter was used to add 10 ml of the liquid growing medium to 50 ml culture tubes. The tubes were plugged with cotton and covered with a metal cap. The agar was steam sterilized in an autoclave for 15 minutes at 1.4 kg/cm^2 . After sterilization, the growing medium was cooled to about 50°C at which time 10 ml of the test solution was added. Sterilizing filtration of the test solution was achieved with a syringe fitted with a .2 micrometer filter mounted in a micro-filtration casing. Filters were steam sterilized in the casing prior to use. This technique allowed for the addition of sterile test solutions without autoclaving.

Extract preparation and clean-up.

Oven-dried tissue of plant materials, used to make cold water extracts, was ground for 2 minutes in a Waring blender. Plant material was soaked in an aqueous

solution for 24 hours at 4°C. After soaking, the solution was filtered through several layers of cheese cloth and then centrifuged at 7×10^7 g. The supernatant was then filtered under suction through a sheet of Whatman #1 filter paper in a Buchner funnel. Extracts were first passed through a 1.2 micrometer filter to facilitate subsequent clean-up with the .2 micrometer filter.

Preparation of bioassay.

Barnyardgrass was used as the test species in all studies with agar culture. Seeds were surface sterilized with a 0.1% HgCl_2 solution, then washed several times with sterile water. After surface sterilization, seeds were planted on petri dishes with unamended agar. Germination proceeded in the dark at 25°C for 24 hours. At this time, a small radicle was visible and served as a guide for selection of uniform seedlings to be planted into the growth medium. Four seeds were planted in each culture tube to which the growing medium had been allowed to solidify at an angle, to provide for a greater planting surface area. Seeds of the test species were securely planted in the growing medium with the radicle just below the surface. The root growing area of the culture tubes was covered with aluminum foil to reduce light exposure to the roots.

Culture tubes were placed on a slanted rack in a growth chamber, which provided exposure to light. The light period was 16 h (30°C) and the dark period was 8 h at 20°C. The length of the growing period varied between experiments.

Sorghum shoot extract toxicity under two nutrient conditions.

Bacto-agar was mixed with two kinds of aqueous extracts. The solution used to make the growing medium were: .01 M potassium phosphate buffer at pH 6.5 and 1/2 strength Hoagland's solution at pH 6.5. The test solutions were: .01 M potassium phosphate buffer and sorghum extract (1 g of dry plant material in 100 ml of .01 M potassium phosphate buffer). Barnyardgrass grew for seven days at which time plants were removed from the growing medium and root and shoot lengths recorded. The treatments were replicated four times and analyzed as a two-way factorial with treatments arranged as a completely randomized block. The factors of the treatments were two levels of Hoagland's solution and two levels of Sorghum extract.

Effect of plant age on sorghum shoot toxicity.

On June 15, 1978, sorghum ('Bird-A-Boo') was planted with a grain drill on a Spinks loamy sand. Two strips of sorghum were planted 3 m wide and 30 m long.

Seeds were planted to a depth of 2.5 cm in rows 10 cm wide. Four weeks after planting, random samples of sorghum of equivalent maturity were harvested and frozen. At two week intervals after this initial harvest, samples were collected in the same way. Samples were obtained until 18 weeks after planting. All samples were kept frozen until dried and ground for extract preparation.

Bacto-agar was mixed with a .01 M potassium phosphate buffer solution to prepare the growing medium. Extracts from the eight harvest dates of the sorghum shoots were prepared by soaking 1 g of the dry residue in 100 ml of .01 M potassium phosphate buffer for 24 h at 4°C. All extracts were adjusted after clean-up within the pH range of 6.3 to 6.5. Two concentrations of the sorghum extract were used as test solutions to determine which concentration would best reveal subtle differences in extract toxicity. The two concentrations used were equivalent to 0.5 g and 0.2 g of dry residue soaked in 100 ml of the buffered solution. Growth in controls was obtained by averaging data from two treatments in which test solutions consisted of distilled water and a .01 M phosphate buffer. Barnyardgrass grew in the culture tubes for five days, at which time plants were removed from the growing medium to record lengths of roots and shoots. Data from the 18 treatments were analyzed as a two-way factorial with levels of the

factors being two rates of sorghum residue and eight harvest dates of sorghum shoots. Trend analysis followed by linear regression were performed on the data.

The response of weed growth to sorghum residue as a mulch and when incorporated into the soil.

Muck Soil.

Sorghum ('Bird-A-Boo') was planted into cedarwood greenhouse flats (36 x 50 cm) on January 6, 1979. Seeds were planted to a depth of 1.2 cm using a pegboard to provide a 72 unit equidistant plant spacing. The experimental design was a 2 x 2 factorial with the treatment factors being sorghum residue regime (either present or not) and soil manipulation (soil well-mixed or undisturbed). The four treatments were replicated four times. Natural glasshouse light was supplemented by metal halide lights at an average light intensity of $842 \mu\text{Em}^{-2}\text{s}^{-1}$. The period of supplemental light was 16 h. Glasshouse temperatures averaged 25°C (day) and 20°C (night). Overhead irrigation was supplied, as needed, usually on a daily basis. The sorghum was grown for 38 days at which time all flats received a glyphosate spray at a rate of .8 kg/ha. Two days after the spray treatment, weeds were removed from all flats. Flats received the soil mixing operation in a Hobart blender 5 days after the spray treatment. On February

20, three weed species were planted in the flats 1-2 mm below the soil surface. Tooth picks were used to mark the location of the seeds so they could be differentiated from volunteers. The weeds planted were: common purslane (Portulaca oleracea L.), redroot pigweed (Amaranthus retroflexus L.) and proso millet (Panicum miliaceum L.). Natural weed populations were also permitted to grow and included in total weed weight for each flat. Weeds were harvested by species to measure dry weight accumulation 22 days after planting.

A similar experiment was conducted using Spinks loamy sand soil. Procedures were the same as outlined above, except the sorghum was planted on April 10, 1979 and grew for 30 days, and an additional indicator species, barnyardgrass (Echinochloa crus-galli L. Beauv.), was utilized in the assay. Two successive plantings of weeds were made 11 days and 39 days after crop desiccation. Weeds were harvested for dry weight accumulation 22 days after planting.

The response of snap beans in response to shoot or root residues of sorghum.

On February 8, 1979, sorghum ('Bird-A-Boo') was planted into cedarwood greenhouse flats (36 x 50 cm) using a Houghton muck soil as the growing medium. Seeds were planted to a depth of 1.2 cm using a pegboard to provide a 72 unit equidistant spacing. The sorghum

grew for 33 days in a glasshouse with supplemental lighting provided by metal halide lamps at an average light intensity of $842 \mu\text{Em}^{-2}\text{s}^{-1}$, after which the plants were desiccated with glyphosate at .8 kg/ha. The soil treatments were prepared 22 days after spraying. The control consisted of fresh Houghton muck soil from the same storage bins used to initially grow the sorghum. The treatment designated 'root' included only the roots of the 33 day-old sorghum in the undisturbed soil in which it was originally planted. The treatment designated 'shoots' consisted of sorghum shoots cut and removed from the flats and placed on the surface of flats containing fresh soil. The treatment designated 'roots and shoots' consisted of flats in which sorghum grew where the shoots were cut and laid on the soil surface. The treatment design was a 2-way factorial (Sorghum x soil manipulation) with treatments arranged in a completely randomized block. Four rows of beans were planted into the flats 7.5 cm apart, on April 4, 1979. Glasshouse conditions for bean growth were the same as that specified for sorghum growth. Bean plants were harvested for dry weight determinations 13 days later. A second crop was planted in the same flats on April 19 and harvested 20 days later; and a third crop was planted May 6 and harvested 20 days later.

RESULTS AND DISCUSSION

Investigation of sorghum shoot extracts in sterile growth medium.

Microfiltration was used to sterilize shoot extracts that were added to sterile liquid agar. Sterilizing filtration was achieved with .45 and .2 micrometer filters. Unfiltered extracts that were not autoclaved had a prolific microbial growth and were still toxic in bioassay. Autoclaving the growth medium containing the sorghum extracts did not affect the toxicity as measured by barnyardgrass growth (Table 1). Buffers were used for making sorghum extracts in a sterile growing medium. Extracts made from sorghum tissue using only distilled water are of a low pH (4.8). A similar observation was made by Guenzie and McCalla (19). To reduce the possibility of low pH toxicity, buffered growth mediums were evaluated for test species growth and sensitivity to sorghum extracts. Tris (HCL) buffer and 0.1M potassium phosphate buffers both had some depressing effect on barnyardgrass. The .01 M potassium phosphate buffer did not alter growth and allowed for an accurate assay of extract influences (Table 2).

To determine if short duration assays could be conducted in a growing medium without nutrients, half-strength Hoagland's solution was compared to no

nutrients. Nutrient solutions inhibited growth in agar with no extracts present and did not provide the degree of suppression with the sorghum extracts as was found where .01 M potassium phosphate buffer was used to prepare the growing medium.

Extracts were made from sorghum shoots ranging in age from 4 to 18 weeks. Two concentrations (.5 and .2 g/100 ml aqueous solution) were evaluated to determine at which rate subtle differences between growth stages could be detected. Both rates responded in the same way with respect to toxicity to barnyardgrass. Trend analysis revealed that toxicity from 4 to 18 weeks increased in a linear fashion (Figure 3). The r^2 value indicated that 58% of the variation with respect to toxicity can be related to various stages of sorghum development.

Growth of snap beans in response to sorghum root or shoot residues.

Bean plants had shown dramatic stimulation in the field where sorghum ('Bird-A-Boo') and sorghum x sudangrass hyb. ('Haygrazer') were present as surface mulches (Chapter 4). Plant parts of roots and shoots were evaluated for their ability to stimulate bean growth. In the first planting, 'roots' and 'roots and shoots' both increased total bean weight over control (Table 4). In the second planting, all plant parts

provided increased dry weight over the control. Treatment means in the third planting were not significantly different.

The trend in bean growth points out several different aspects of the stimulatory effect of sorghum. Both roots and shoots were able to stimulate bean growth, although initially the roots were more effective. Bean growth in the second planting revealed an influence from sorghum shoots. The response indicates that the agent of stimulation (assumed to be chemical) must be initially released and must accumulate to a given level to provide stimulation. Whether it is by direct or indirect (microbe) interaction was not ascertained. By the third planting, all stimulation was lost. This could indicate either microbial decay or leaching to remove or alter the agent of stimulation. Sorghum shoots were fairly well intact at the end of the experiment, roots, however, were well decomposed. Addition of mineral nutrients by the sorghum to elicit stimulation is not likely because of high level of fertility maintained with regular watering with solutions of (20-20-20 at 1 g/l) soluble fertilizer. The glasshouse study supports the notion that bean stimulation as observed in the field was not due to a physical influence of the mulches, but due to something being released into the soil environment.

The response of weed growth to surface or soil incorporated sorghum residues.

The introduced indicator for the various treatments on the muck soil were: common purslane, redroot pigweed and proso millet. Volunteer weeds which grew during the experiment were also included in total weed biomass for each flat.

A significant interaction of sorghum residue x soil manipulation indicated that weeds did not respond in the same way to sorghum as a surface mulch compared to incorporation into the soil (Table 5). As a mulch, sorghum reduced weed biomass by 70% over the non-mulched no-till control. When incorporated, sorghum increased weed biomass 25% over the non-crop tilled control. Using a mineral soil, two weed harvests from the same flats provided information on how sorghum residues can affect weed growth over time. The weed species planted in this experiment were: common purslane, redroot pigweed, proso millet, and barnyardgrass. The first harvest provided similar results as that found on the muck soil. Sorghum as a surface mulch reduced total weed biomass by 82% over the non-mulched control (Table 6). Sorghum incorporated into the soil resulted in a 64% increase in total weed biomass. The change in sorghum response with soil manipulation is significant by virtue of a significant F-test for the interaction of these two factors. These experiments on both muck

and mineral soils allow for several hypotheses, assuming chemical release from sorghum residues as the cause in altered weed growth over no crop controls. In the first harvest, weed suppression may be the result of a high level of toxins in the soil surface where weed seeds are germinating. Incorporation of the residues may dilute or enhance degradation to a point where stimulation can occur. The ability of a growth regulating compound to be detrimental to growth at a high concentration and stimulatory at lower concentrations is common in plants. The second harvest from the mineral soil demonstrates that the toxic effect of the sorghum is lost. Compounds released by sorghum are concentrated at toxic levels in the few days after desiccation. Leaching or microbial activity may have reduced them to stimulatory levels in the second harvest.

CONCLUSION

The use of sterile agar provided a good means of studying root absorbed toxins without the complicating factor of microbial activity. Sorghum shoot extracts showed a trend towards increasing activity with increasing age of living plants. Increased activity along with increased biomass can provide weed suppression from surface mulches over a 4-6 week growth period.

The previously reported stimulation of field grown snap beans with residues of sorghum was substantiated in the glasshouse study. This finding and others like it can find application in devising rotation patterns (23, 24) which seek to maximize yields. Further work in this area has been initiated and may reveal the agent and mechanism of stimulation.

The study of weed and crop growth in response to sorghum residues adds new insight for its use as a mulch in no-tillage plantings. If initial activity of sorghum can complement weed control obtained with other herbicides, the stimulatory effect which occurs later, can benefit the cash crop. As we strive for improvements in cropping systems, with limited energy resources, reseachers must integrate strategies from natural ecosystems along with the developments of modern technology.

Table 1. The effects of autoclaving and microfiltration on the sorghum shoot extract bioassay. Growth of barnyardgrass measured by fresh weight of roots and shoots.

Autoclaving	Filtration	Shoot wt. (μg) ^a	Root wt. (μg)
+	None	257	220
	0.34 micrometers	236	203
	0.2 micrometers	228	254
-	None	244	193
	0.34 micrometers	226	233
	0.2 micrometers	238	228

^a Autoclaving x filtration interaction not significant at 5% level. Means within a column are not different.

Table 2. The effects of buffer type and concentration in the growing medium of the sorghum shoot extract bioassay. Barnyardgrass growth measured by sight rating as percent reduction over control (test solution of .01 M potassium phosphate buffer in plain agar).

Buffer Type (in growing medium)	Buffer Concentration	(-) sorghum extract	Growth Rating ^a (+) sorghum extract
Potassium Phosphate	.01 M	0	75
	.1 M	18	81
Tris (HCL)	.01 M	36	76
	.1 M	83	78

^a Test solution x buffer type x buffer concentration interaction significant at the 1% level. LSD at 5% level = 10 for all means presented.

Table 3. The effect of nutrient solution (1/2 strength Hoagland's) in the growing medium of the sorghum shoot extract bioassay. Barnyardgrass growth measured by root length.

Nutrients in growing medium	Root Length (cm) ^a	
	(-) sorghum extract	(+) sorghum extract
None	9	4
1/2 strength Hoagland's	8	7

^a Growing medium x test solution interaction significant at 1% level. LSD at 5% level = .8 for all means presented.

Figure 3. Linear regression of root length as % of control vs. age (weeks) in the field of 'Bird-A-Boo' sorghum shoot extract.

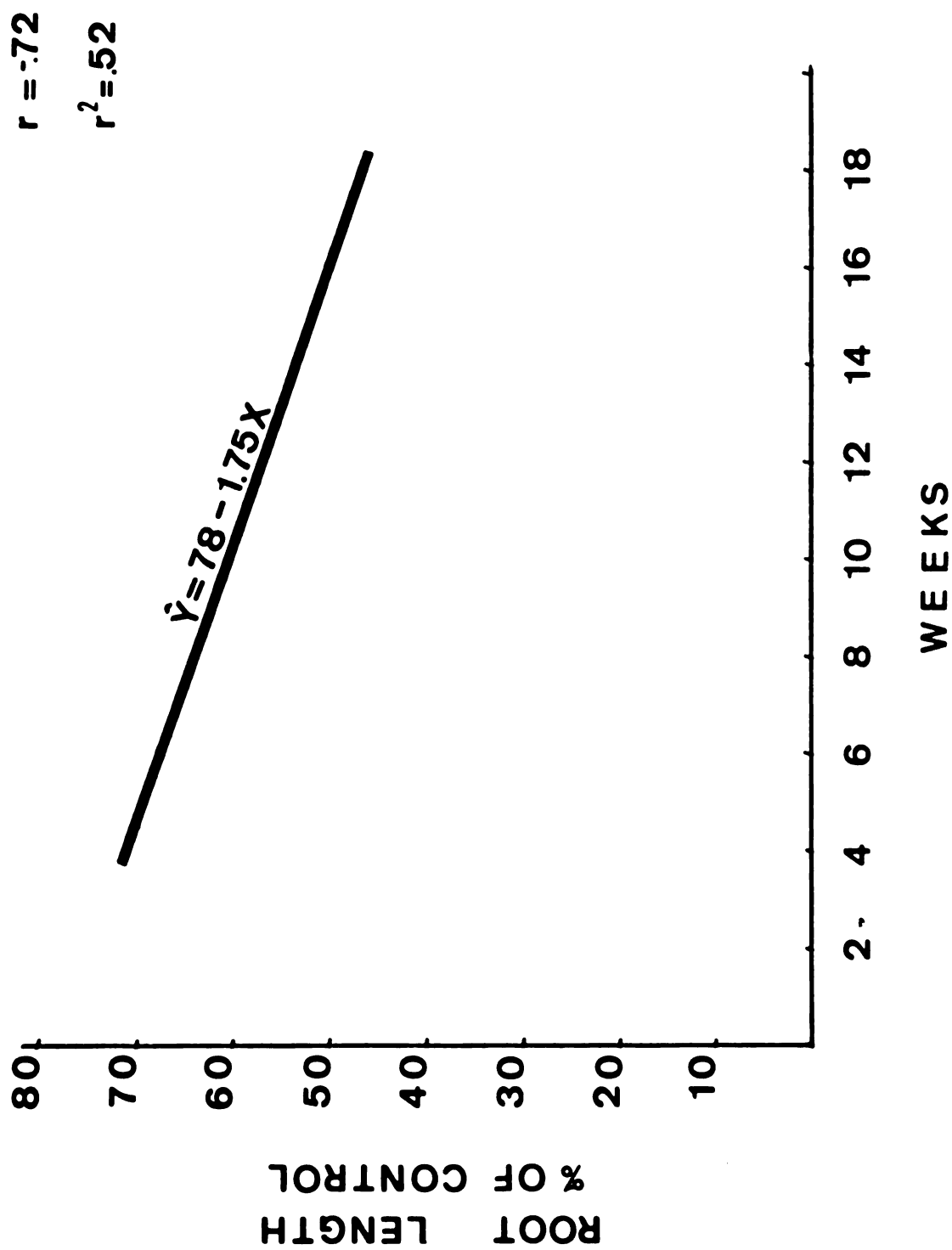


Table 4. Dry weight of snap beans grown in Houghton muck soil as influenced by various parts of the sorghum plants.

Sorghum plant part	g/flat ^a		
	1st planting	2nd planting	3rd planting
No residue	23	28	26
Roots	29	36	29
Shoots	25	33	28
Roots and Shoots	31	38	26
LSD 5%			
	5	4	NS

^a Includes all plants that grew in the flats.

Table 5. Total weed biomass as influenced by sorghum residues and tillage on a Houghton muck soil.

Tillage	Sorghum Residue	Total Weed Biomass (g/flat) ^a
(-)	(+)	3.3
(-)	(-)	10.8
(+)	(+)	18.4
(+)	(-)	14.7

^a Residue x tillage interaction significant at 5% level.

Table 6. Total weed biomass as influenced by sorghum residues and tillage on Spinks loamy sand. Treatment means for two successive harvests from the same flats.

Tillage	Sorghum Residue	g/flat ^a	
		1st harvest	2nd harvest ^b
(-)	(+)	1.0	10.0
(-)	(-)	5.7	6.1
(+)	(+)	11.3	10.0
(+)	(-)	10.2	5.6

^a Residue x tillage interaction significant at 5% level.

^b Effect of residue significant at 1% level.

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