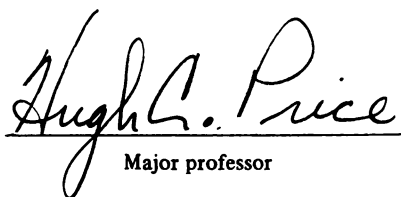


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RESPONSE OF FLUID SOWN AND TRANSPLANTED TOMATO
IN REDUCED TILLAGE SYSTEMS

By

Daniel Thomas Drost

A THESIS

Submitted to
Michigan State University
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ABSTRACT

RESPONSE OF FLUID SOWN AND TRANSPLANTED TOMATO
IN REDUCED TILLAGE SYSTEMS

By

Daniel Thomas Drost

This study was initiated to determine if fluid drilling principles could be utilized in no-tillage tomato production systems. Emergence of pregerminated seeds was faster than raw seed regardless of tillage system, however, final stands were similiar for both seeding methods. Tomato stands in rye residues were greater than in conventionally tilled soils. Soil temperatures were similiar in all tillage systems and did not influence stand establishment. Early growth of direct seeded tomatoes in rye and wheat residues was reduced and flowering delayed compared to conventional tillage. This growth reduction was further expressed as a 38% and 24% yield reduction in the rye and wheat residues, respectively. In contrast, growth and yield of transplants was not influenced by tillage system. In greenhouse studies, emergence of germinated tomato seeds was not influenced by rye residues, however, seedling growth was severely inhibited. Furthermore, glyphosate treated rye was more toxic to seedlings than paraquat treated rye.

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CHAPTER 1

LITERATURE REVIEW

Reduced Tillage Systems

There have been significant changes in soil tillage over the last 40 years. The standard practice of 10-14 passes over the field during the production year has been reduced to two or three times (96). Intensive cultivation to prepare the land and control weeds has been partially replaced with herbicides. Faulkner (35), in *Plowman's Folly*, questions the use of the mold board plow and remarks about the problems associated with its use.

Numerous names have been used to describe reduced tillage production systems. Zero-tillage, conservation tillage, stubble mulch planting, strip-tillage, reduced tillage, minimum tillage, sod-planting and no-till are all used to describe the phenomenon of a reduction in tillage operations to the soil. These practices all attempt to minimize tillage and create as favorable an environment as possible to maintain or enhance crop production while providing efficient soil and water conservation (62). Since the first tests by Sprague in 1952 (88) and Davidson and Barrons in 1954 (25) with the substitutions of herbicides for tillage, to the estimated 7.1 million acres of no-tillage (NT) crops planted in 1981, interest in an alternative method of land preparation has developed (3). The concepts of

NT are well documented, however, users must develop new skills to insure the system functions properly.

The advantages of NT farming include such benefits as reduced soil erosion by water and wind, reduced energy usage, increased water use efficiency, improved soil structure and porosity, temperature regulation and plant protection. Erosion of the top soil has become one of the major concerns of crop scientists around the world. Faulkner in the early 40's proposed that erosion was reduced by a mulch left on the surface and nutrient availability improved (35). Erosion may be due to either water or wind. Moody (68) reported seven times higher runoffs on unmulched plots as compared to mulched plots. This reduction of runoff was a major factor in maintaining a greater supply of soil moisture and reduced evaporation under the mulched conditions. Eroded soils carried by the wind frequently damage or kill plants. Survival studies on green beans (Phaseolus vulgaris L.) (87), tomatoes (Lycopersicum esculentum Mill.) (1), cabbage (Brassica oleracea L.), carrot (Daucus carota L.), pepper (Capsicum annuum L.), onion (Allium cepa L.) and cucumber (Cucumis sativus L.) (32, 38) all illustrate the potential damage to seedlings by blowing sand. In all cases but cucumber, growth and yields were consistently decreased. Woodruff et al (105) states that good vegetative cover on the land is the most permanent and effective way to control wind erosion. Height and quantity of the stubble, as well as orientation in relation to the wind, all influence the reduction in wind erosion.

NT practices reduce runoff and evaporation losses from the soil (12, 56, 68). Higher levels of soil moisture were present in NT plantings than conventional tillage (CT). Blevins et al. (12) showed

higher volumetric moisture content in NT plots during much of the growing season. This greater water reserve under the NT system may carry the crop through periods of short term drought. The largest difference between NT and CT were seen at depths of 0-8 cm.

NT and reduced tillage systems help to maintain and improve soil structure. Wetting and subsequent drying of the soil surface causes physical changes in the upper few millimeters that can make it more dense, decrease the size and amount of large pores and reduce the surface permeability to air, water and plants (33). This compact layer is commonly called a soil crust or cap. Minimum or NT systems allow dead vegetation to protect the interrow area, reducing crusting and increasing water infiltration (59). Davidson and Barrons (25) measured soil aggregates in a sandy loam which had been in quackgrass (Agropyrens repens L.) for four years. They compared cultivated to uncultivated soils several months after the sod was killed, either with chemicals or ploughing. A 20% decrease in soil aggregation was found following cultivation. Sprague et al. (89) noted a 63% reduction in soil aggregates in the top inch of soil after plowing a fall seeded rye (Secale cereale L.)

Van Wijk (103) looked at the effects of oat (Avena sativa L.) straw mulch on the soil temperature and early growth of corn (Zea mays L.). Data collected in Iowa, Ohio and Minnesota support the theory that early season growth is decreased by low temperatures caused by a mulch of crop residue. In South Carolina where soil temperatures are higher, oat mulch did not appreciably influence corn growth rates. Moody (68) reported similiar results with corn grown in wheat (Triticum aestivum L.) mulch. Growth was depressed early in the



growing season, however, increases in growth and subsequent yields were attributed to favorable moisture conditions under the mulch. This relationship of reduced soil temperatures and increased soil moisture may be beneficial later in the growing season, but may adversely affect germination and growth early in the season.

No-tillage techniques have considerable economic impact on agricultural production. NT practices have increased yields, reduced equipment investments, lowered production costs, expanded land use, enhanced double cropping and decreased energy use (106). Power and labor demands are high in intensive cultivation systems, especially during planting periods (96). Direct drilling into untilled soils can hasten field operations and crop establishment. With lower energy demands, fewer field operations and labor requirements, NT farming can reduce production costs at a time when energy and labor are scarce. Although NT farming offers many benefits, without proper management, yield differences will not result in greater profits (106).

A major reason for the 10-14 tillage operations used in producing row crops during the era before selective herbicides was to control weeds (97). No-tillage, which is a spray, plant and harvest operation, relies completely on herbicides for weed control. A particular herbicide combination may not control all weed species present and continued use of one combination may result in shifts in weed populations (98). This requires changes and/or rotations in crop and herbicide combinations. These population shifts result in species that survive well in the absence of cultivation. "Contact" or "knockdown" herbicides such as glyphosate (N-(phosphonomethyl)glycine) or paraquat (1,1'-dimethyl-4,4'bipyridinium ion) are required to control vegetation



that has emerged at the time of planting (104). At the same time, one or more residual herbicides are needed to control germinating annual grasses and broadleaf weeds.

Insect control methods in NT production systems need further investigation. Larson (61) reported poor corn seedling emergence and increased incidence of soil insect damage. Mulch cover associated with reduced tillage provides an ideal environment for the development and survival of most insects that attack corn. Black cut worm populations attacked 15% of the seedlings in NT cornfields and only 1% in adjacent fields tilled conventionally (72). Approximately four times as many corn root worm eggs were found in NT soils as compared to CT. Methodology is available for the management of many pests (48). Through integrated pest management and regular field observations, severe damage to plantings can be averted.

No-tillage farming employs methods directly opposed to the principles of destroying infected tissue before they can infect new crops (61). It has been shown that some plant pathogenic fungi and bacteria overwinter on residues from diseased plants of the previous season (73, 101). Thus, residues may be the primary source of large amounts of inoculum for disease development. Monoculture with reduced tillage has been shown to allow certain pests to increase due to host susceptibility and pathogen specificity (13). Crop rotation will break this link and keep inoculum at tolerable levels. Doupnik et al. (31) found that growing sorghum (Sorghum vulgare L.) under minimum and NT practices reduced the incidence of stalk rot by 44% and 72%, respectively. As a result, yield increases were 44% and 41 %, respectively for the minimum and NT systems compared to CT. Integrated



pest management and crop rotations may become the major methods of controlling many diseases of crops in a reduced tillage system.

Excellent reviews of crop residues and phytotoxicities have been made by McCalla and Norstadt (67) and Rice (82). Phytotoxic substances can be produced from crop residues in three possible ways (29). First, phytotoxic substances can be released directly from the residue as it decomposes in the field. Second, surface additions of residues can result in the stimulation of select microorganisms, which in turn produce phytotoxic substances. Finally, the addition of crop residues to soil can result in a stimulation of microorganisms, which are themselves, pathogenic to the crop being grown. Guenzi and McCalla (51) reported that residues of wheat, oats, soybeans (Glycine max L.), sweet-clover hay (Melilotus indica L.), corn, sorghum, bromegrass (Bromus tectorum L.) and sweetclover stems contain water-soluble substances that inhibit the germination and growth of corn, sorghum and wheat. The growth inhibition from phytotoxic substances is greatly dependent upon the degree of decomposition of the plant residues in the soil (52). Norstadt and McCalla have shown that stubble-mulching of wheat results in a shift of the soil fungal populations (74). During certain periods of the year conditions are favorable for the growth of a Penicillium which is known to produce patulin, a phytotoxic compound.

Allelopathic properties of mulches have been reported by Patrick (76, 77), Overland (75), DeFrank and Putnam (27) and Barnes (5). Rye residues reduced weed biomass by 68-95% when compared to controls with no residues (5). DeFrank (26) reported that residues of rye and wheat provided a 70 and 90% weed reduction respectively and stimulation of pea growth. In vegetable compatibility trials, stands of

tomatoes and carrots were severely reduced by sorghum residues, whereas stands of cabbage and snap beans were increased. Weed biomass was also reduced by residues of sorghum and sudangrass (Sorghum sudanense).

Weed control in NT planting still poses some problems. Vegetative mulches can control weeds through shading and in some instances allelopathic leachates. Beste (7), Standifer and Beste (90), Hiller (54), Putnam (79) and Campbell and Anderson (17) have studied the use of chemicals to control covercrops and weeds. Glyphosate and paraquat have been found to be effective in retarding the growth of rye and wheat mulches used in NT plantings (54). Herbicidal activity was adequate but not equally effective in all treatments (7). Varying amounts of tillage late in the year were required to control weeds.

Rodrigues (83) found that when wheat plants were treated with glyphosate at 6.72 kg.ha^{-1} , .5 to 1.0% of the applied glyphosate was exuded from the plants, and freshly planted corn and soybean plants growing in the same pots showed signs of injury. Devine (28) reported that 1.6% of the absorbed ^{14}C -glyphosate was exuded from quackgrass after 10 days. Only .1% of the glyphosate was uptaken by soybean roots. It was felt that the likelihood of such transfer between weed and crop is much reduced in a field setting. Barnes (5) reported that chemically desiccated rye residues reduced germination of lettuce (Lactuca sativa L.) and barnyardgrass (Echinochloa crusgalli L.) and reduced the growth of tomato. Several possible explanations were given for the noted results. First, exudation of the chemical from rye roots or shoots may be responsible. It is also possible that the stress of the chemical treatment caused the rye to produce and release more toxic natural products. Finally, the chemical may have remained

on the plant tissue where it was absorbed by the plants as they grew through the residues.

Limited tillage in vegetable crops has not been practiced or studied as extensively as in agronomic crops (90). The main reasons are that most vegetables are short duration, high value crops that require intensive management. Intensive management includes such things as; (i) complete spray coverage of the plant for insect and disease control, (ii) precise seeding equipment, (iii) cultivation needed for weed control and (iv) harvesting equipment designed to operate on bare soils (7). Yield reductions associated with management failures have a greater impact on vegetables which result in lower income, regardless of energy or time savings. Moreover, fewer herbicides are labeled for use in vegetable cropping systems, thus restricting the grower from obtaining complete weed control with available compounds (90).

Cabbage, cucumber, squash (Cucurbita moschata Duch.), tomato, sweet corn, snap beans, lima beans (Phaseolus lunatus L.) watermelon (Citrulus lanatus L.) and asparagus (Asparagus officinalis L.) have been grown successfully under NT (8, 9, 30, 58, 79, 90, 93). There have been conflicting reports on the yields of some vegetables. Morse (69) reports cucumber (cv. Poinsett) grown in a NT system had a higher marketable yield than when grown in CT. Beste (9) in work at Maryland, reported a significant yield reduction of cucumber (cv. Poinsett) in NT plots. He also reported that the early growth of direct seeded tomatoes to be greater in the NT plots compared to the CT plots (8). Yields were equivalent, however, in the no-tillage areas, yields matured earlier. Doss studied the influences of

tillage, nitrogen and rye cover crop on the growth and yield of transplant tomato in Alabama (30). Nitrogen was reported to have no consistent effect on marketable yield, however, yields were 2.2 MT/ha higher for the no-rye plots than for plots with rye. A no-tillage planting system for vegetables appears feasible, and the protective mulch covering should reduce seedling injury from wind erosion. NT culture of vegetables should allow growers to plant and harvest under conditions where it would be too wet for moving machinery onto conventionally tilled soils (58).

Seed production in carrots and onions is labor intensive. Also, both crops are poor competitors with weeds. Campbell and Anderson (17) studied the effects of no-tillage and herbicides on onion and carrot seed production. Comparisons of tillage methods indicated a significant reduction in seed yield for both crops relative to the no-tillage plots. Seed production of either crop growing in conventionally tilled plots was not affected by chemical treatment. In contrast, chemical treatments applied to carrot and onion significantly reduced the seed yield within the no-tillage method.

Fluid Drilling

Direct seeding vegetables has been examined as a way of reducing production costs associated with transplanting. Direct seeded vegetables emerge more slowly under field conditions due to cold soils, destructive soil pathogens and soil crusting; all of which contribute to poor germination and erratic emergence (22, 84). The inability to control environmental factors, germination and emergence have restricted the full implementation of direct seeding. Further more,

until reliable stand establishment is achieved, direct seeding practices will not be fully utilized.

The sowing of pre-sprouted seeds has been investigated as a means of overcoming the problem of uncontrollable environmental factors associated with field seeding (15, 19, 41, 42, 46). To date, seeds of over 20 crops, including a range of various types of vegetables, flowers, cereals, fodders, grasses and trees have been pregerminated and fluid drilled. Early work on fluid drilling was conducted at the National Vegetable Research Station in Wellesbourne, England. It was hypothesized that if vegetable seeds could be imbibed or germinated under ideal conditions and then sown in the field, both the uniformity of the crop stand and the rapidity of emergence in the field could be improved (22).

Fluid drilling is not solely a specialized field drilling operation; it is an integrated system involving (i) treatment and germination of the seed prior to sowing, (ii) separation of germinated from ungerminated seeds, (iii) storage of germinated seeds, (iv) preparation of the gels for suspending the seeds and (v) the drilling of the germinated seeds (43).

The advantages of germinating seeds before planting are numerous. Specific requirements can be met that will give maximum seed emergence. These requirements include optimum temperature, adequate oxygen, water and light where necessary (19). Seeds of some species are sensitive to chilling injury or seed exudates that reduce germination and emergence. Others are influenced by light or temperature induced dormancies. By germinating the seeds under ideal environmental conditions

prior to planting in the field, many of these germination problems can be overcome.

Temperature is critical for the germination of tomato. Harrington (53) and Thompson (94) characterized the temperature ranges for germinating tomato as having a threshold around 10°C and ceasing as it approaches 40°C. The optimum range was between 15 and 30°C. Bussel and Gray (15) reported raw seed germinated at 10°C took 41 days to reach 50% emergence. Pregerminated seeds emerged after 17 days. At higher temperatures (18°C), emergence was reduced to 11 and 5 days for raw and pregerminated seeds, respectively. Gbate et al. (41) and Gray et al. (47) reported that sowing pregerminated tomato seeds have given 2 to 19 days earlier emergence when compared to dry seed. Soil temperatures at planting had the greatest influence on seedling emergence. At early planting dates, 34% more pregerminated seeds emerged than dry seeds (47). Sowing pregerminated carrot seed has given about five to nine days earlier emergence as compared with dry seed for sowings made when soil temperatures were between 9 and 20°C (22). Similiar results have been reported by Gray (45) and Finch-Savage (37) for lettuce when pregerminated seeds were sown in soil temperatures below 10°C. The maximum benfits of fluid drilling pregerminated seeds are when seeds are sown under adverse soil temperatures.

Gray (44) reported that the thermodormancy problems and light requirements of lettuce can be met by pregerminating the seed. Furutani (39) has shown similiar results with celery (Apium graveolens L.) seed. Incubation at 32°C of seeds pregerminated at 10°C, produced a 80% stand while only 3% of dry seeds emerged.

Pregerminated seeds were not affected by high temperature (32°C) in the seed bed, since they had already germinated and were past the stage of thermodormancy. Use of pregerminated seeds overcomes the thermodormancy problem encountered when raw seeds are sown directly in the soil.

Seed exudates leached into the soil stimulate microbial activity which may influence germination (86). Celery seed leachates are known to contain coumarin compounds, which may also inhibit germination (40). Furutani reported that at 10°C more than 90% of the celery seed germinated in light with leachates removed, while only 72% germinated without leachate removal (34). At temperatures that can induce dormancy (24°C), over 80% of the seeds germinated when seed leachates were removed. Without leachate removal, about 25% germinated.

Taylor et al. (91) used a sucrose density technique to separate germinated from ungerminated seeds of celery and pepper (Capsicum annuum L.). Over 95% of the ungerminated seeds were removed from seed lots by this method. Separated, germinated celery seeds gave 95% seedling emergence as compared to 83% for unseparated, germinated seeds. For pepper seeds, the corresponding figures were 98% and 76%.

Pregerminated seeds that can not be immediately planted need to be stored in an environment that restricts further radicle elongation without damaging the seed. Brocklehurst et al. (14) stored germinated onion, carrot, cabbage and lettuce seed at 1°C in aerated conditions for 15 days without serious loss of viability. Radicle growth continued in lettuce and cabbage which could lead to radicle damage when the seeds are handled for sowing. Carrot and onion seed continued to germinate but no substantial radicle elongation occurred. Storage

of tomato seed at 5°C has been reported to have no effect on seedling emergence (10). Storage of pregerminated tomato seed in small quantities of gel has been successful for up to 20 days at 0°C (78). Percent emergence and Emergence Rate Index for 0°C stored seed was greater than raw seed.

Darby (23) lists several essential characteristics of gels used for fluid drilling. The gels should suspend the seed, be easily mixed and pumped, non-phytotoxic, breakdown in the soil and be inexpensive. In these studies, fluid drilling of vegetable seeds was shown to improve seedling emergence, but the benefits were influenced by the gel used and the moisture stress encountered in the field. Pill and Fieldhouse (78) reported that the type of gel used influenced the storability of pregerminated tomato seed at 0°C. Vittera II, Hydrogel, Laponite and SPG104K all adversely affected the percent emergence and Emergence Rate Index of stored seed, while Natrosol 508 HHR had little damaging effect. Selection of gels that are non-phytotoxic to seed is important.

Lickorish and Darby (63) describe a small, portable hand operated fluid drill. Dimensions for construction are given along with methods of loading and unloading the gel/seed mixture. Ghatge et al. (42) compared a compressed air and pump system to plant pregerminated seed. The compressed air system delivered gel/seed mixture into the furrow under constant pressure. The pump system worked by squeezing flexible tubing to extrude the gel. Both systems operated well in the laboratory as well as in the field, although the compressed air system was easier to operate than the seed-gel pump and delivered more uniformly in continuous planting.

Uniformity of seedling emergence is important for plant uniformity at harvest. Germination of celery seed in the field is slow and sporadic, resulting in delayed and nonuniform stand establishment, especially under cool soil conditions. Therefore, most celery crops are started in greenhouses before transplanting into the field. However, even under greenhouse conditions, celery seed germination can be very nonuniform. Currah et al. (22) and Biddington et al. (10) established earlier and more uniform celery stands with fluid drilled pregerminated seed. Furutani showed that by pregerminating celery seed at 10°C for 14 days before planting in the greenhouse, transplants grew larger and were more uniform in height, number of leaves and dry weight than plants grown from raw seed (39). It was believed that more uniform transplants would produce more uniform celery stalks. Gray attributed 60 to 90% of the variation in mature head weight and date of head maturity could be accounted for by variation in the date of seedling emergence (43). Seedling variation in size was due to non-synchronous germination, variation in size at emergence or a combination of these factors. Sowing pregerminated seeds reduced the time and spread of both emergence and maturity compared with size graded seed sown conventionally. Currah observed that one third of the variation in harvested plant weight with carrot was caused by competition and two thirds by variation in seedling weight (20). Uniform spacing of the plants had almost no beneficial effect on the uniformity of root size. It was proposed that any method to reduce the spread of seedling emergence would result in more uniform size. Methods included selection of high quality seed, seed size grading, seed priming, fluid

drilling pregerminated seeds, uniform depth of planting, adequate soil moisture at planting and avoiding soil crusting.

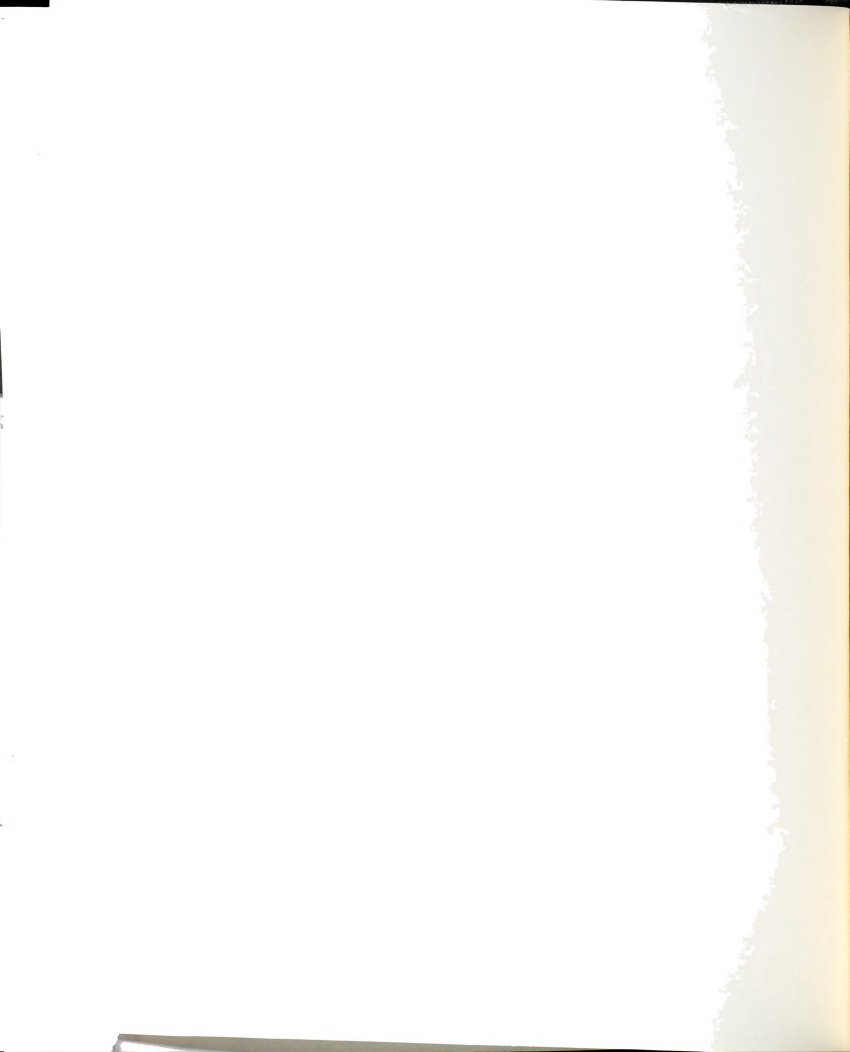
There have been several reports of increased yields resulting from fluid drilling pregerminated seed. Biddington et al. (10) noted increased earliness and yields were obtained by sowing pregerminated celery seed. Currah et al. (22) showed that fluid drilling pregerminated carrot seed, increased yields after 64 days from planting but not after 77 days when compared to raw seed. Lipe and Skinner (64) showed that pregerminated onion seed gave two weeks earlier emergence than dry sown seed. This earlier emergence resulted in two weeks earlier maturity and 30% higher yields as compared to sowing dry seed. Fluid sown pregerminated tomatoes ripened 6 to 11 days earlier than dry seed and gave higher total yields, yield of ripe and marketable fruits (47). Earliness was attributed to 15 days earlier emergence than conventionally sown dry seed from sowings made when mean soil temperatures ranged from 9°C to 11.5°C.

INFLUENCE OF SOIL TEMPERATURE, MOISTURE AND
TILLAGE SYSTEM ON THE EMERGENCE
OF TOMATO AND WEEDS

Abstract

Field studies were initiated to study the influences of no-tillage soil management systems on fluid sown tomatoes. Soil temperatures in no-tillage and conventionally tilled plots were not different in 1981 or 1982. Soil temperatures in the seeding zone (5 cm) warmed rapidly after early planting and were considered near optimum for seed germination. Soil moisture levels were higher in the wheat mulch than in the conventionally tilled soils in both year, however, higher moisture levels existed under rye residues than conventionally tilled in 1982, but not in 1981. Moisture levels in the seed zone (0-7.5 cm) for most sampling dates were lower than all other depths throughout the growing season.

In three of four experiments, stands of direct seeded tomatoes in rye mulch were higher than those in conventionally tilled soils. Early plantings had lower emergence than late plantings. Sowing pregerminated seeds resulted in greater total emergence, hills and lower T50 emergence than raw seed. Differences between raw and pregerminated seeds were greater when planted under sub-optimal conditions. There was no difference in emergence between raw and pregerminated seeds at late planting dates.



CHAPTER 2

INFLUENCE OF SOIL TEMPERATURE, MOISTURE AND TILLAGE SYSTEM ON THE EMERGENCE OF TOMATO AND WEEDS

Introduction

Field seeding of tomatoes (Lycopersicum esculentum Mill.) in the midwest is often restricted by cool, wet conditions that delay planting and inhibit emergence. Rains during and after planting may cause soil crusting which reduce stands. In addition wind and sand blast injury is a serious problem where tomatoes are seeded on sandy soils. Slow emergence or seedling injury often results in reduced stands of diseased plants that can reduce yields. Large acreages of tomatoes are transplanted due to difficulty in stand establishment with direct seeding. Crop establishment from transplants tends to be more reliable but costs associated with the growing and planting can make it restrictive. It was hypothesized that fluid drilling and no-till planting are methods that can speed emergence and protect the seedlings from sand blasting as well as reduce the cost associated with conventional tillage.

Although tomato seed germinate well over a wide range of temperatures from 15- 35°C (94), the rate and final percent germination is markedly reduced below 12-15°C. Sowing pregerminated seed with radicles 2-3 mm long reduced the time from sowing to seedling emergence to 17 days as compared to 41 days in untreated seeds at temperatures of 10°C, and 5 days compared to 11 days at 18°C (15). Gray et al. (47)



reported that fluid sown pregerminated seeds of outdoor bush tomatoes emerged 15 days **earlier** than conventionally sown dry seed from sowings made when mean soil temperatures ranged from 9.0 to 11.5°C. The percent seedling emergence was 57 and 65% from early and late plantings, 34 and 24% higher, respectively than from dry seed sown conventionally. With faster and higher emergence at low temperatures, sowing tomato seed in cool spring soils is a distinct possibility.

The production of agronomic crops using reduced tillage has been an accepted practice for more than a decade. Yield increases have been associated with more efficient use of soil moisture. Blevins and Cook (11) reported that the difference in seasonal moisture in a no-till (NT) management system to be higher in volume percent moisture to a depth of 24 inches. They attributed this higher moisture to conservation associated with soil conditions that maintain good surface infiltration, reduction in evaporation due to surface mulch and the absorption power of the decaying roots and surface mulch.

The possibility of lower than normal temperatures in residue covered soils has caused some concern regarding the use of conservation tillage system. Van Wijk et al. (103) showed corn (Zea mays) growth early in the season was decreased by low temperatures caused by a mulch of crop residue. In areas where soil temperatures are warmer in the spring, a mulch did not affect corn growth rates. Griffith et al. (50) noted cooler soil temperatures under strip coulters planting systems versus conventional plantings in northern and central Indiana. Growth of corn was delayed with reduced tillage systems during the first eight weeks at these locations. Where growing seasons

are limited, early season plantings and growth are necessary if NT practices are to be adopted.

Maintaining vegetative cover on the soil surface is the simplest way of controlling wind and water erosion (36). A cover crop is any crop used to control erosion. Generally it is planted when the primary crop is off the land, but may be planted in strips or between rows to provide protection for vegetables or other crops highly susceptible to abrasive injury in the seedling stage. Studies on the effects of wind blown soils on tomatoes (1), green beans (Phaseolus vulgaris L.) (87) and peppers (Capsicum annuum L.) (32) showed decreased stands and yields associated with soil abrasive injury to plants. NT plantings have the potential to reduce this problem

Current research in limited tillage methods in vegetable production have studied planting crops through mulches of crop residues. Beste and Olsen have investigated planting vegetables through a rye (Secale cereale L.) mulch to protect the seedlings from wind erosion on sandy soils (9). Their studies showed yield increases with sweet corn, lima beans (Phaseolus lunatus L.) and watermelon (Citrullus lanatus Thunb.) grown in NT systems as compared to conventional tillage (CT). Beste noted earlier growth and maturities of direct seeded tomatoes grown in NT plots (8). Final yields in both the CT and NT plots were equivalent. He felt that NT planting of vegetables was feasible and should reduce seedling injury from wind erosion. DeFrank and Putnam compared weed control effectiveness of mulches of barley (Hordeum vulgare L.), oats (Avena sativa L.), rye, sorghum (Sorghum bicolor), soybeans (Glycine max L.), sudangrass (Sorghum sudanese) and wheat (Triticum aestivum L.) (27). Crabgrass (Digitaria sanguinalis)



and purslane (Portulaca oleracea L.) populations were reduced by 98 and 50% respectively with residues of sorghum. Barnes (5) reports similiar weed control properties with killed rye residues. Barnyard-grass (Echinochloa crusgalli L. Beauv.) and redroot pigweed (Amaranthus retroflexus L.) biomass was reduced 74 and 55% respectively under rye residues. This control was partly due to allelopathic leachates from the mulch. Guenzi and McCalla (52) reported that residues of several crops contain water soluble substances that inhibit the germination and growth of corn, sorghum and wheat. Patrick et al. (77) studied the effects of plant residues on lettuce (Lactuca sativa L.) growth under field conditions. Their results showed that toxic materials were confined to decomposing residues and that phytotoxicity was most severe after 10 to 25 days of decomposition.

Reliable plant establishment of direct seeded tomatoes has been a major concern of growers using raw seed. In Michigan many vegetable growers plant rye as a fall cover crop and use it as a green manure or windbreak for transplanted and direct seeded vegetables. This study was undertaken to determine the effects of NT on direct seeded vegetable production and how to fully utilize the beneficial effects of both cover crops and fluid drilling. The objective of these studies were to evaluate (1) the differences in emergence of fluid sown tomato in a no-tillage system and (2) to monitor moisture and temperature differences under a reduced tillage system.

MATERIALS AND METHODS

Cover Crop Influences on Soil Temperature

Soil temperatures were recorded three times daily over the growing season in 1981 and 1982 at the Sodus Horticulture Research Farm and



MSU Horticulture Farm, respectively. Sensors were placed at 5, 15 and 25 cm depths for each cover crop and read at 8:00 am, 12:00 am and 5:00 pm. There were three replications in 1981 and four in 1982.

Temperature was monitored with an integrated circuit temperature sensor and a standard voltage meter. Data was summarized to obtain a weekly average temperature which was the average of the daily readings. Differences in the various cover crops and depths were evaluated and data analyzed by analysis of variance.

Effect of Tillage System and Depth on Soil Moisture

Soil moisture levels were determined for the three tillage systems at various intervals from the time of planting. In 1981 moisture determinations were made on an Oshtemo sandy loam and in 1982 on a Marlette fine sandy loam. Two randomly selected sites were sampled in each tillage system and moisture content for the 0-7.5, 7.5-15.0, 15.0-22.5 and 22.5-30.0 cm depths determined. There were three replications in each year. Moisture content was determined gravimetrically and volume moisture content calculated. Volume Moisture Content (VMC) was calculated using the following formula:

$$VMC = \frac{\left(\frac{S_w - S_d}{w_d} \right)}{V}$$

VMC = Volume Moisture Content

S_w = Weight of Wet Soil (g)

S_d = Weight of Dry Soil (g)

w_d = Density of Water (1 g/cm³)

V = Volume of Soil (cm³)



Effect of Two Fall Sown Cover Crops on Tomato Stand Establishment (1981)

Two cover crops were fall seeded in 1980 in a Oshtemo sandy loam soil with a Moore-Uni-Drill. Planting date, seeding rate, kill date and residue production are listed in Table 1. Main plots were conventional tillage (CT); rye mulch, no tillage (NT) and wheat mulch (NT); and subplots were two seeding methods and three planting dates. Potash (224 Kg/ha) and ammonium nitrate (56 Kg/ha) were broadcast over all plots and incorporated prior to seeding the cover crops. The conventional tillage control plot was also planted with rye. Plots were 15 x 18 meters and there were four replications.

One week prior to spring planting, rye and wheat NT plots were sprayed with paraquat (1'1-dimethyl-4,4'-bipyridium ion) at a rate of 1.1 Kg/ha + .5% (v/v) X-77 non-ionic surfactant. The control plots were disked to knock down the standing rye, plowed and disked again. Napropamide (2-(α -naphthoxy)-N,N-diethylpropionamide) was applied to the CT plots at a rate of 1.1 Kg/ha and incorporated. Residue densities for the NT treatments were determined by sampling a 1m² area per plot, drying at 50-60°C and weighing.

Tomato seeds (UC 82) were germinated in the laboratory for 72 hours at 25°C. Germination of four lots of seed (20 g/lot) took place in plastic buckets filled with distilled water and aerated by an air-stone in the bottom of the bucket. The water was changed daily. Raw and pregerminated seeds were sown in the field on May 7, May 19, and June 2, 1981 with a tractor mounted fluid drill. The planter was calibrated to deliver 220 liters of gel/ha. Seeding rate was equivalent to 560 grams of dry seed/ha. A 1.5% (w/v) solution of gel, Vittera II, Napera Chemical Co. (potassium propenoate propenamide) was used to suspend

Table 1. No-tillage cover crop residue production.

Experiment	Cover Crop	Seeding	Planting Date	Kill Date	Biomass
		Rate (kg/ha)			(kg/ha)
Two Fall Sown Cover Crops	Rye	134	9/22/80	4/27/81	2976
	Wheat	134			1672
Five Fall Sown Cover Crops	Rye	134	9/30/80	5/22/81	---
	Wheat	134			---
	Oats	134			---
	Ryegrass	11			---
	Sunflower	11			---
Early Planted Tomatoes	Rye	134	10/13/81	5/03/82	881
	Wheat	134			252
Late planted Tomatoes	Rye	134	10/13/81	5/27/82	2935



seeds. The gel/seed mixture was gravity fed to a modified peristaltic pump and then extruded through 9 mm I.D. plastic tubing. The tube went to a planter and was positioned to deposit the gel immediately behind the furrow opener. The pump was modified to space the gel/seed mixture at 25 cm intervals. There were approximately 3-6 seeds in each 4-6 ml of gel. Rows were spaced at 1.5 meters. Emergence data was recorded 14 and 28 days after seeding for all tillage treatments, seeding methods and planting dates. Total number of plants and hills were analyzed by analysis of variance.

Effect of Five Fall Sown Cover Crops on Tomato Stand Establishment (1981)

Five cover crops were drilled in a Lapeer sandy loam soil at the Clarksville Horticultural Research Station. Seeding date, rate and kill date are given in Table 1. The experimental design was a split plot with four replications. Rye (cv. Wheeler), wheat (cv. Tecumseh), oats (Avena fatula L. cv. Mariner), ryegrass (Lolium multiflorum Lam.) and sunflower (Helianthus annuus L.) constituted the main plots; and two cultivars and seeding methods were subplots. Plots were 10.5 x 10.5 meters with 1.5 meter row spacings. The control plot was fall sown rye, plowed and disked twice before seeding. All NT plots were sprayed with paraquat (1.1 kg/ha + .5% X-77 surfactant) seven days prior to seeding. Granular fertilizer (672 kg/ha of 6-24-24) was broadcast over all plots on May 27.

Pregermination and fluid drilling techniques were as described previously. Tomato (cv. UC 82 and Peto 80) were planted on May 29. Stand counts for all plots were taken 14 days after planting. Data were analyzed by analysis of variance.

Effect of Rye and Wheat on Early Planted Tomatoes and Weeds (1982)

Fall sown rye (cv. Wheeler) and wheat (cv. Tecumseh) were planted with a grain drill at the Horticultural Research Station at MSU in a Marlette fine sandy loam. Planting date, seeding rate, kill date and residue production are listed in Table 1. Main plots were three soil management systems and subplots were two planting methods and dates. There were six replications. Plots were 6.1 x 7.6 meters with 1.5 m row spacings. A conventional tilled plot, fall seeded rye with spring plowing and two diskings was included as the control. Ammonium nitrate (168 kg/ha) was applied to all plots prior to planting.

Paraquat (1.1 kg/ha + .5% X-77 multifilm surfactant) was applied to all NT plots on May 3, 1982. Raw and pregerminated tomato seeds were fluid drilled on May 8 and May 27. Seeds were germinated and sown as described previously, except the gel/seed mixture was spaced at 30 cm intervals with 2-3 ml of gel per glob.

Daily emergence counts were taken until no more seeds emerged for three consecutive days. Total emergence, number of hills and days to 50% emergence (T50) were calculated for all treatments. Daily temperature readings and weekly moisture contents were gathered. Three 30 cm² areas in each plot were sampled to evaluate the effects of mulches (coverings) on weed populations and biomass production.

Effect of Rye Mulch on Late Planted Tomatoes and Weeds (1982)

Planting date, seeding rate, kill date and residue production are listed in Table 1. Whole plots were rye mulch (NT) and rye mulch, plowed down and disked twice. Subplots were two seeding methods, raw and

pregerminated seeds, fluid drilled. There were three replications. Plots were 4.5 x 7.6 meters with 1.5 meter rows.

Tomatoes (Chico III) were planted on June 2. Seeds were germinated and sown as described previously. Seeds were stored at 5°C for 24 hours because weather conditions would not permit planting. Daily emergence counts were gathered until no seedlings emerged for three consecutive days. Total emergence, number of hills and T50 emergence were calculated for all treatments. Weed populations from three 30 cm² areas in each plot were counted, harvested and dried for biomass determinations. Data were analyzed by analysis of variance.

RESULTS AND DISCUSSION

Cover Crop Influences on Soil Temperature.

Weekly average soil temperatures in 1981 warmed progressively from 15 Days After Planting (DAP) until 50 DAP (Figure 1). Soil temperatures during this period were not significantly different for the CT and NT plots. By the fourth week, temperatures in the rye and wheat mulch were higher than the CT and remained that way throughout the remainder of the season. Temperature differences 60 DAP were 28.4 and 28.0°C, respectively, for the rye and wheat mulch as compared to 27.0°C for the conventional tillage treatment.

Soil temperatures, during 1982, never got above 20°C during the sampling period (Figure 2). Early season temperatures appeared higher for the wheat mulch than for either the rye or CT plots, however, this difference was not statistically different. Temperatures at early planting were between 10 and 15°C, near the minimum required for tomato seed germination. Temperatures increased to between 17.5 and 20°C by the

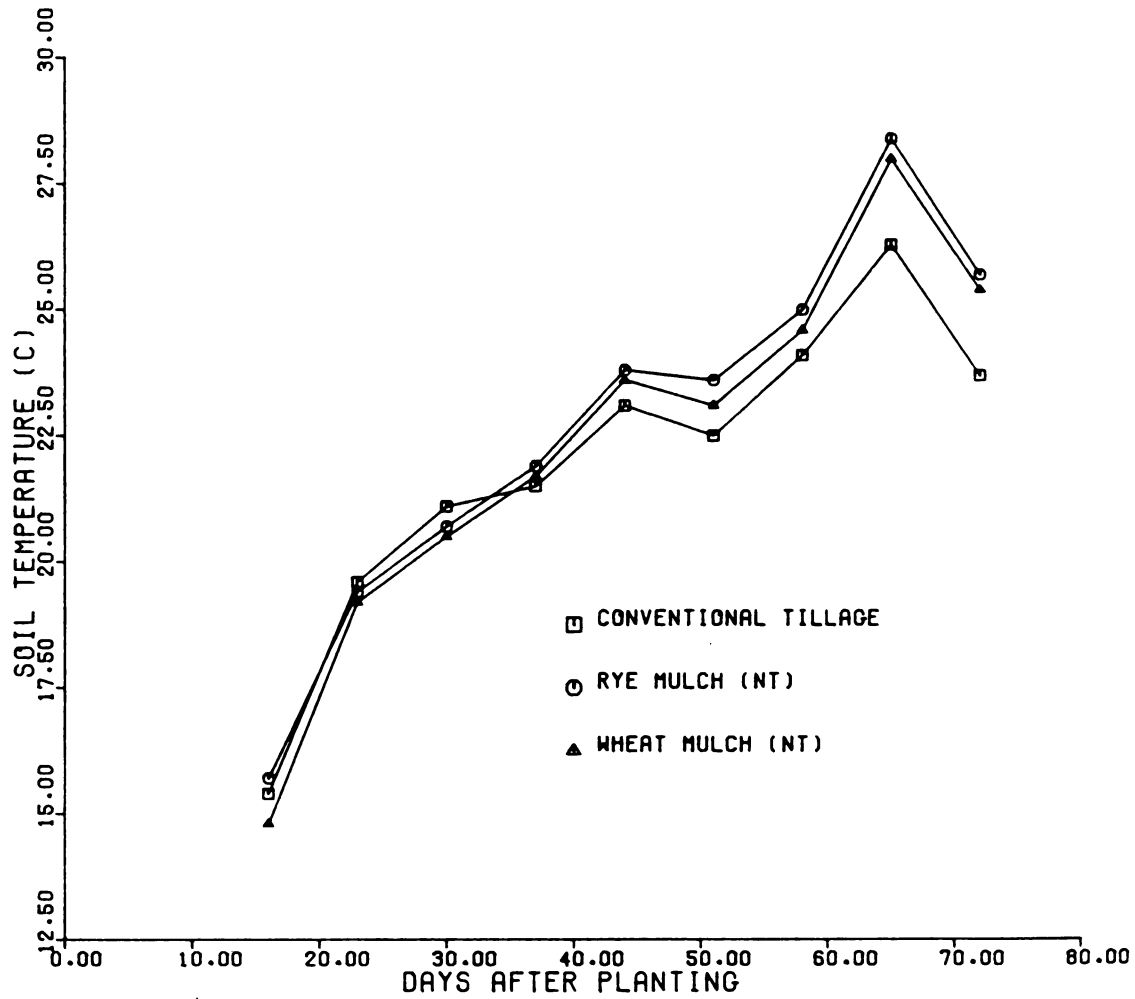


Figure 1. Weekly mean soil temperature as affected by three tillage systems during the first 80 days after the May 7 planting date in 1981.



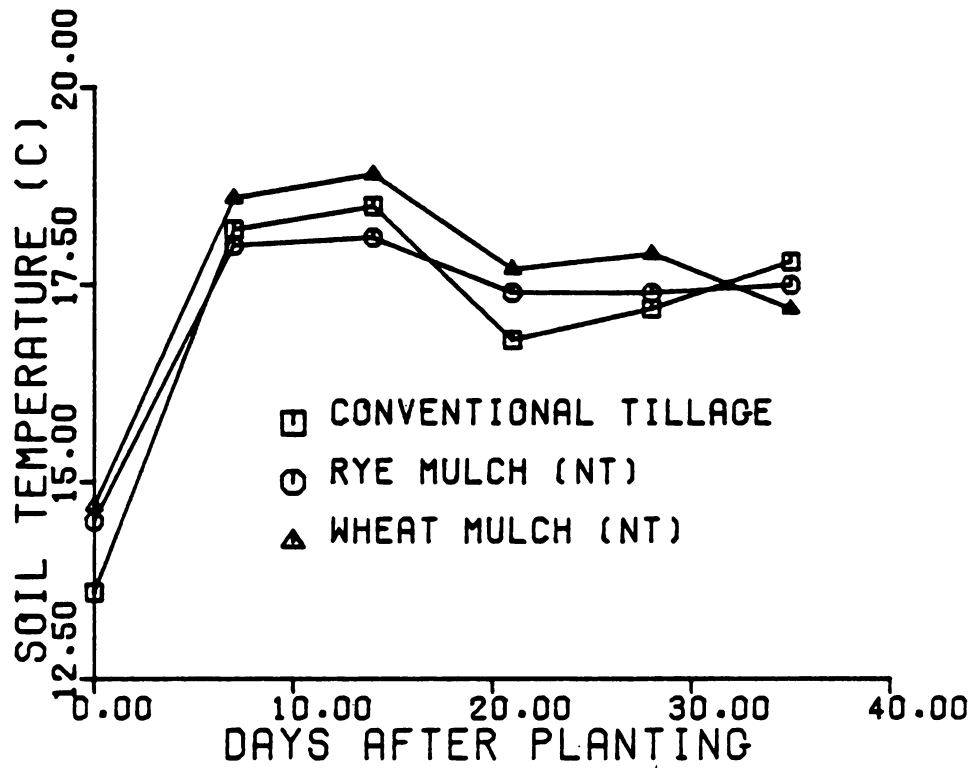


Figure 2. Weekly mean soil temperatures as affected by three tillage systems during the 40 days after the May 8 planting date in 1982.

EXHIBIT 101

second week. At the second planting, temperatures were nearing optimum for seed germination.

Soil temperatures decreased as depth beneath the surface increased (Figure 3 and 4). Mean weekly temperatures were greatest at the 5 cm depth for all weeks in both 1981 and 1982. Soil temperatures in the 5 cm depth increased rapidly by the second week of sampling. Soil temperatures in the seed zone at the May 19 and June 2 planting dates in 1981 were considered near optimum for seed germination, unfortunately equipment failure prevented recording temperatures for the May 7 planting in 1981 (Figure 3). Lower soil temperatures in 1982 may have influenced seed germination at the May 8 planting date, however, temperatures had warmed sufficiently by May 27 to provide a near optimum growing conditions (Figure 4). Temperature differences under the various cover crops appeared to be minimal in both years and should have little bearing on emergence differences. Differences during any week in 1981 or 1982 for the different tillage systems was not greater than 2°C. Lack of differences between the cover crops could have been due to insufficient replications. The interaction of tillage system and depth were not significant in 1981 or 1982. Soil composed of sandy loams, on which many vegetables are grown, appear to warm sufficiently in the spring to allow early seeding and stand establishment of tomato, even under NT conditions.

Effect of Tillage Systems and Depth on Soil Moisture

Soil moisture levels fluctuated greatly during the 1981 growing season (Figure 5). During most of the growing season NT wheat mulch had a higher volume percent moisture level than did either CT or rye

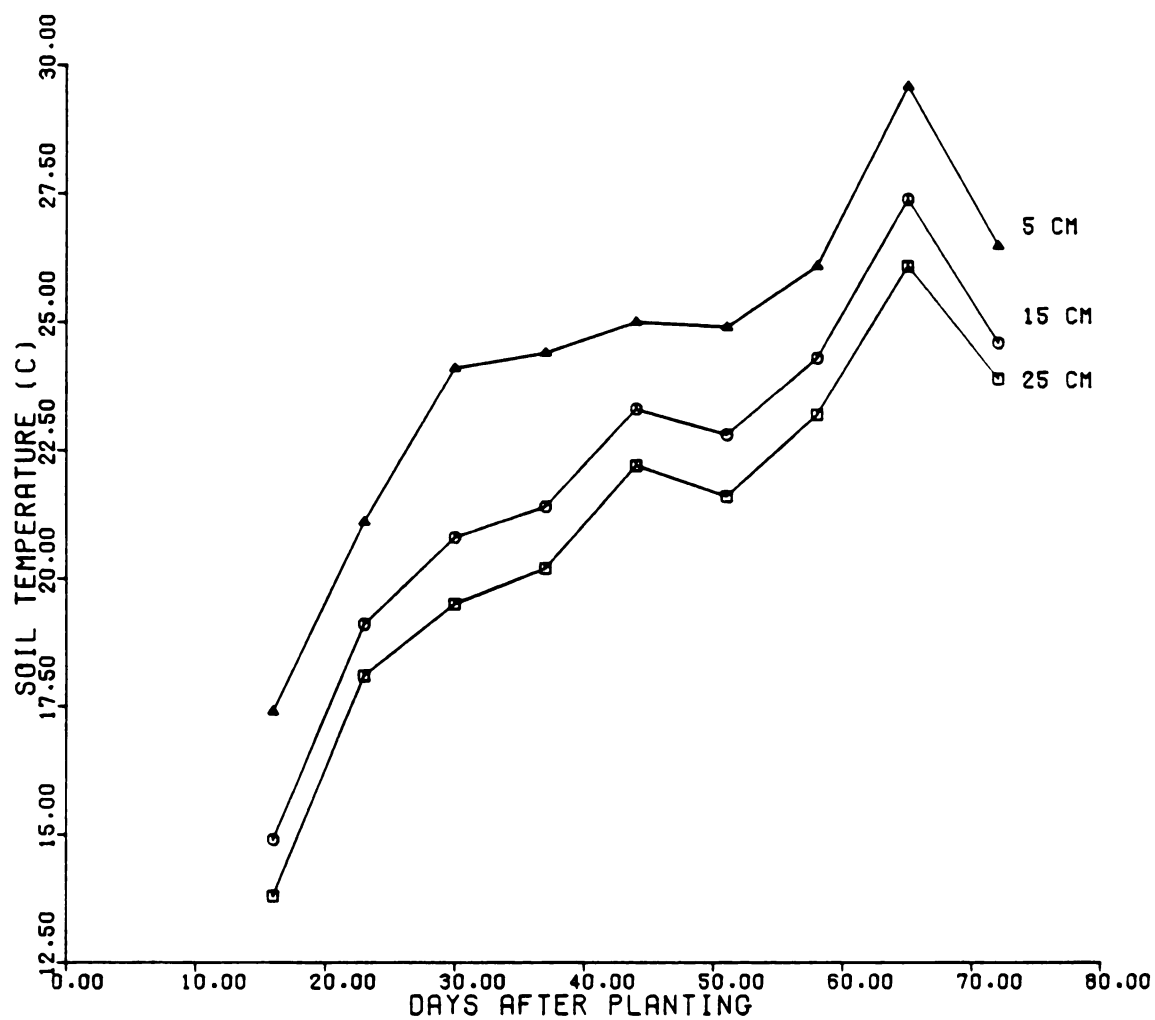


Figure 3. Weekly mean soil temperatures at the 5, 15 and 25 cm depth during the first 80 days after the May 7 planting date in 1981.



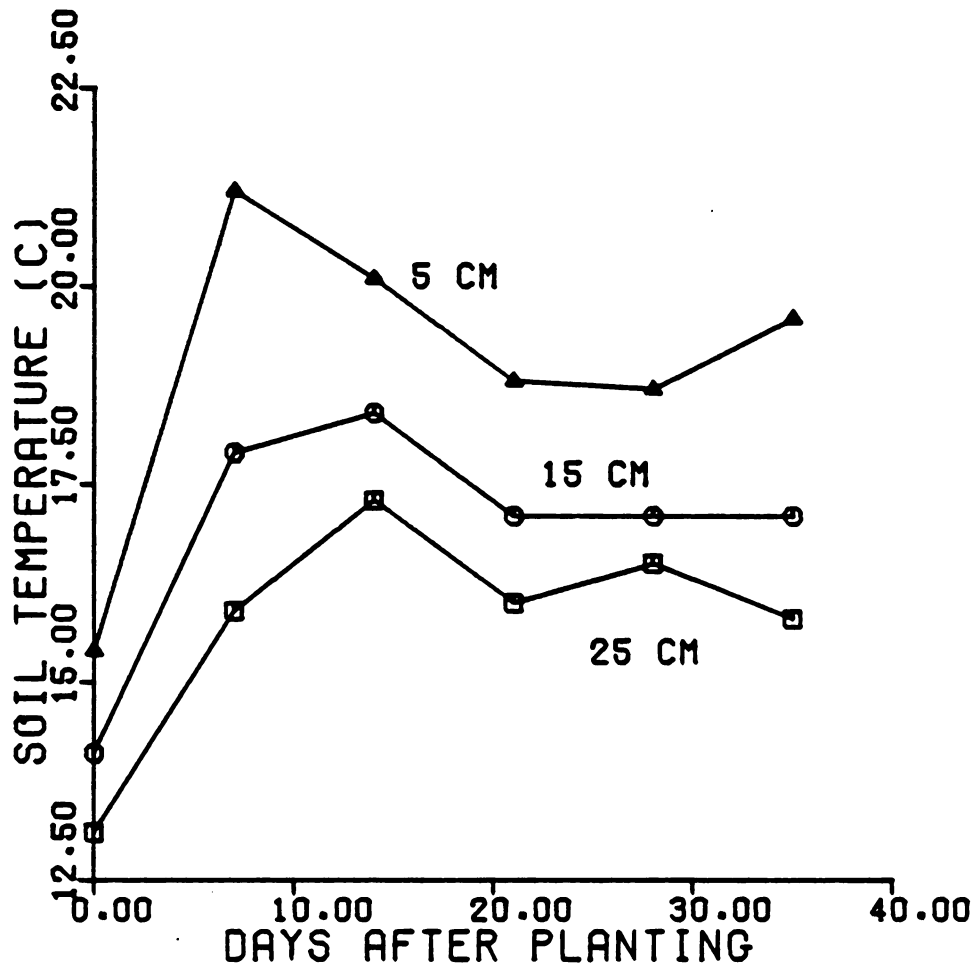
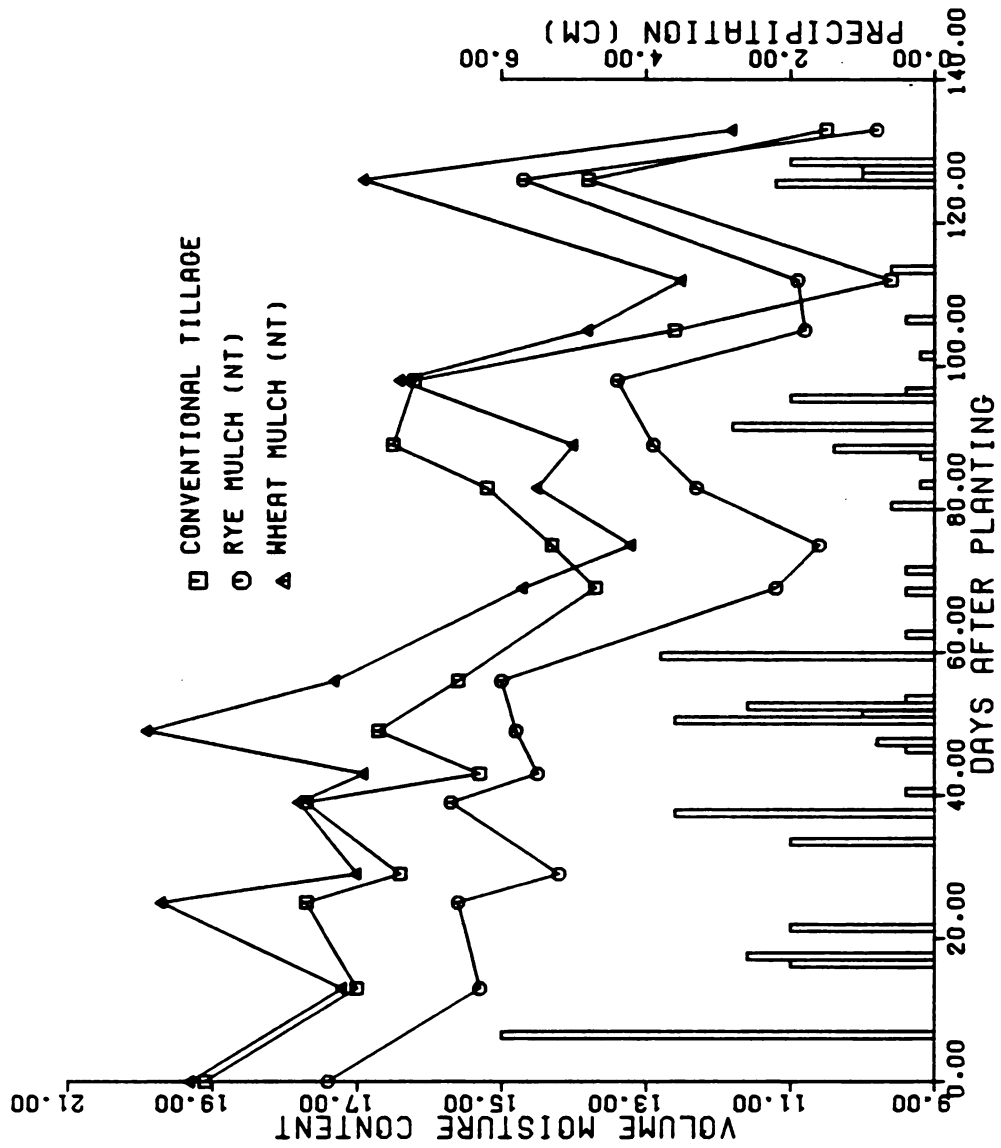


Figure 4. Weekly mean soil temperatures at the 5, 15 and 25 cm depth during the 40 days after the May 8 planting date in 1982.



Figure 5. Influence of three tillage systems on the volume moisture content of an Oshtemo sandy loam throughout the 1981 growing season. Each data point is the mean of four sampling depths and three replications.



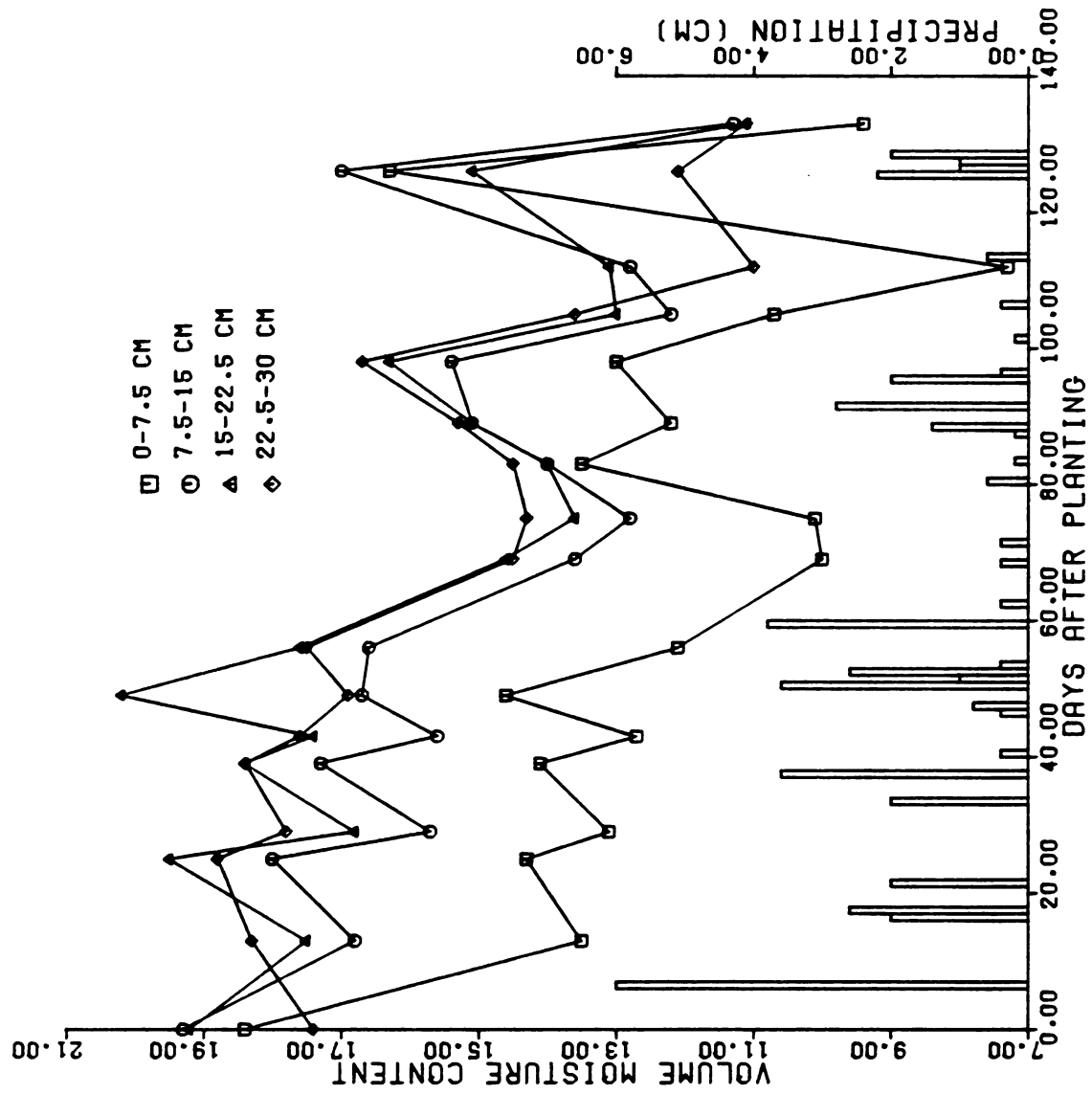


mulch. Moisture content in the rye NT treatments was always lower than in the CT or wheat mulch except late in the season. Heavy rainfalls during the first 60 DAP kept the soil moisture content high in all plots. Soil moisture levels decreased between 60 and 90 DAP as a result of low rainfall during this period. Heavy rains between 90 and 100 DAP (7.4 cm) helped recharge soil moisture levels. A mulch on the soil surface during the late part of the growing season may have contributed to the higher moisture levels found in the NT plots.

Moisture levels in the 0-7.5 cm layer were significantly lower throughout the growing season in 1981, except in late August (Figure 6). Moisture levels between the depths of 7.5 and 30.0 cm were not significantly different from each other. Moisture content was generally higher at the deeper depths. Periods of high rainfall during the first 60 DAP helped to maintain soil moisture levels at the depths between 7.5 and 30.0 cm, however, moisture levels at the surface were still lower. Several weeks of low rainfall 100 DAP lowered moisture levels in the 0-7.5 cm depth to less than 8 percent. Moisture levels for the depths of 7.5-15.0, 15.0-22.5, and 22.5-30.0 cm did not drop as sharply. The interaction of tillage system and depth was not significant.

Rye mulch had a significantly higher moisture level than conventional tillage in 1982 (Figure 7). There was no difference between the CT and wheat mulch at the first two samplings, however, at the last two there was more available moisture in the wheat mulch than in the tilled. Rainfall for May was 4.6 cm. The benefits of the mulches in a year of low rainfall on soil moisture retention are evident.

Figure 6. Volume moisture content of an Oshtemo sandy loam with soil depth throughout the 1981 growing season. Each data point is the mean of three tillage systems and three replications.



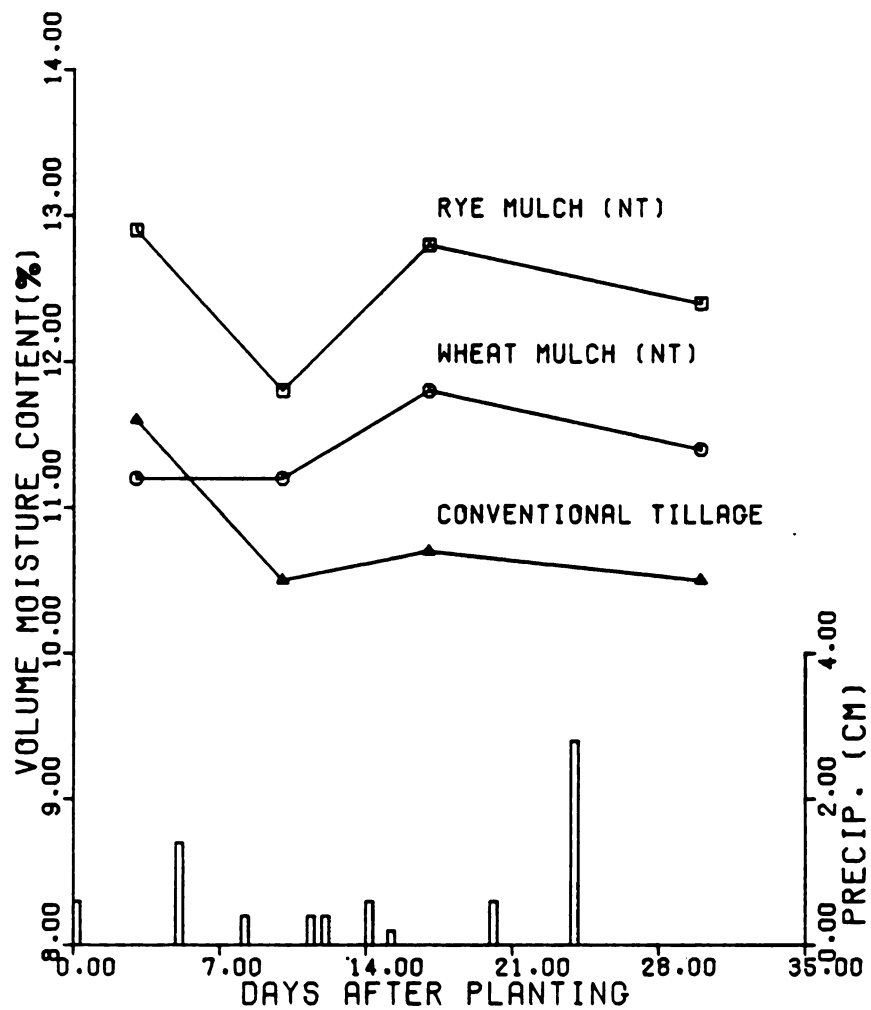


Figure 7. The effects of three tillage systems on the volume moisture content of a Marlette fine sandy loam throughout the 1982 growing season. Each data point is the mean of four sampling depths and four replications.



The effects of sampling depth on soil moisture in 1982 are shown in Figure 8. Trends were similar to 1981, although, there were differences in soil types. Moisture levels were lower in the 0-7.5 cm depth during all weeks when compared to all other depths. Moisture levels were generally lower for the 22.5-30.0 cm depth than for the 15.0-22.5 cm depth.

The benefits of a surface mulch on soil moisture conservation have been described by Blevins and Cook (11) and Jones, Moody and Lillard (56). Wheat mulch in both 1981 and 1982 had a higher volume moisture percentage than did a CT soil, however, soil moisture content under the rye mulch was more variable. It was expected that both NT treatments would have a higher moisture content. Soil moisture is normally lost from the plant root zone by evaporation from the soil, runoff from the surface, transpiration by growing plants and percolation to depths beyond normal root growth (11). Mulches reduce evaporation and runoff but have little effect on transpiration by growing plants. Data for 1981, in which heavy mulches were present on the soil surface, suggest that there is little benefit from rye as a surface mulch for the conservation of soil moisture, however, data in 1982 suggests otherwise. Even during periods of high rainfall in 1981, moisture levels under the rye mulch were significantly less than either the CT or wheat mulch (NT). These contradicting results suggest possible problems in the experimental design, sample size or sampling method. Inherent variability in soil types within any location may have contributed to differences noted. Results in 1982 clearly demonstrate the benefits of a surface mulch on soil moisture conservation, especially in a year where rainfall was limiting.

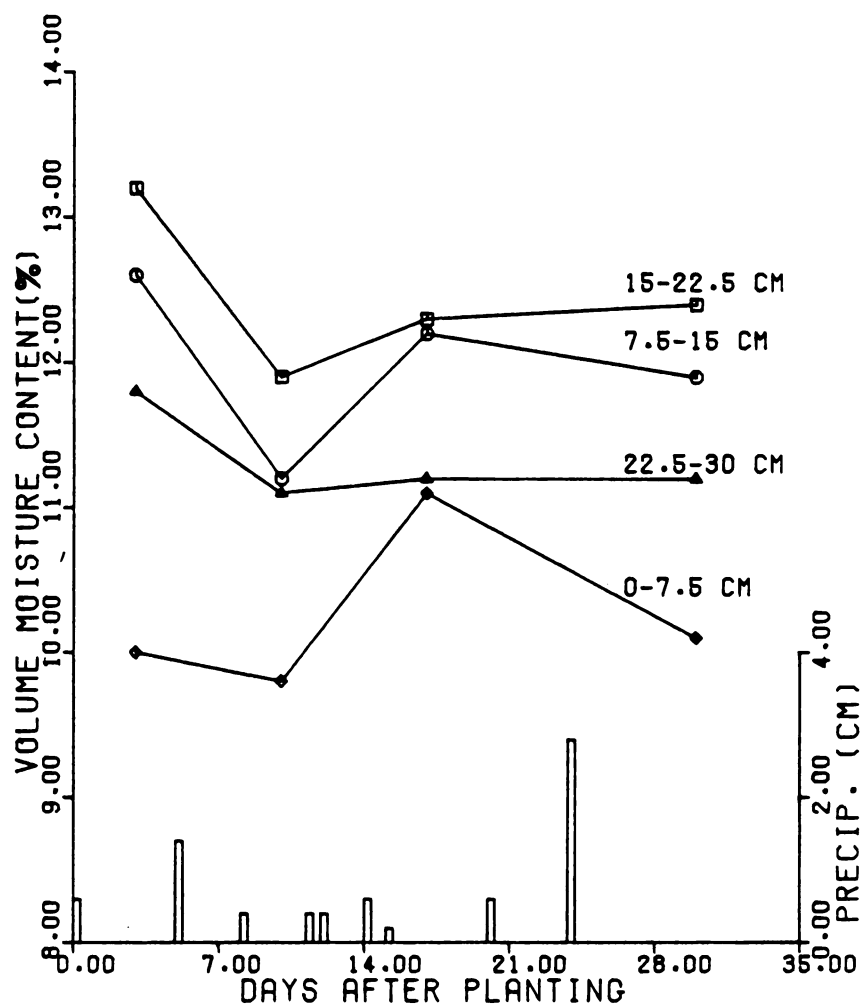


Figure 8. Volume moisture content of a Marlette fine sandy loam with soil depth throughout the 1982 growing season. Values are the means of three tillage treatments and four replications.



Effect of Two Fall Sown Cover Crops on Tomato Stand Establishment (1981)

Stands of direct seeded tomatoes 14 days after planting in both NT plots were significantly less than conventionally tilled plots at the May 7 planting date (Table 2). There was a 29 and 43% reduction in stands for rye and wheat mulch, respectively. There were no differences between the tillage treatments in the number of emerged seedlings at either the May 19 or June 2 planting dates. Fluid drilled, pregerminated seeds had twice as many seedlings emerge 14 days after planting as raw seed for the May 7 and May 19 planting dates (Table 3). There were no differences between the seeding methods at the June 2 planting date.

Stand counts taken 28 days after seeding showed a significant reduction in the number of seedlings emerged in the rye mulch at both the May 7 and May 19 planting dates when compared to the conventionally tilled plots (Figure 9). Stands of tomato in the wheat mulch were less than the conventionally tilled plots for the May 7 planting date, but not for the May 19 planting date. There were, however, no differences between tillage treatments at the June 2 planting date. Similarly, there was a 57 and 49% reduction in the number of hills of tomatoes for the rye and wheat mulches, respectively, when compared to the conventionally tilled plots for the May 7 planting date (Table 4). There were no differences between the conventional tillage and the wheat mulch at the May 19 date, however, there was a 55% reduction for the rye mulch. Late season plantings had no influence on the number of hills of tomato.

A greater number of seedlings emerged from pregerminated seed than raw seed also sown in gel (Table 5). There was significantly higher

Table 2. Effect of tillage system on the emergence of tomato 14 days after planting.

Tillage System	Emergence No./15m ^x		
	Planting Dates		
	May 7 ^z	May 19 ^z	June 2 ^z
Conventional Tillage	41.5	80.4	180.5
Rye Mulch (NT)	29.5	46.0	151.4
Wheat Mulch (NT)	23.7	84.4	194.3
LSD .05	16.4	NS	NS

^xEach figure is the mean of two seeding methods and four replications.

^zThe interaction of tillage system x seeding method was not significant.

Table 3. The effect of seeding method on the emergence of tomato 14 days after planting.

Seeding Method	Emergence No./15m ^x		
	Planting Dates		
	May 7 ^z	May 19 ^z	June 2 ^z
Raw Seed	32.5	72.4	174.2
Pregerminated Seed	69.3	138.4	176.6
LSD .05	10.0	16.0	NS

^xEach figure is the mean of two seeding methods and four replications.

^zThe interaction of tillage system x seeding method was not significant.

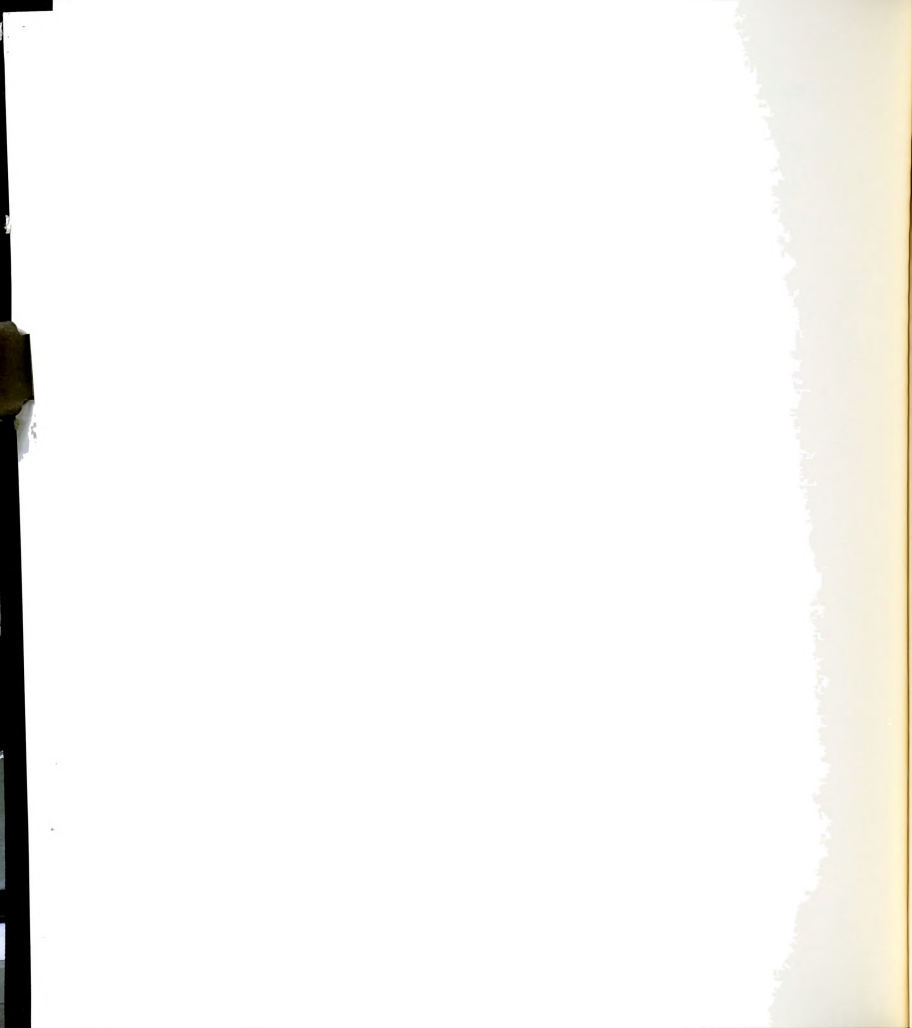


Figure 9. The interaction of tillage system and planting date on the number of plants per 15 meters.

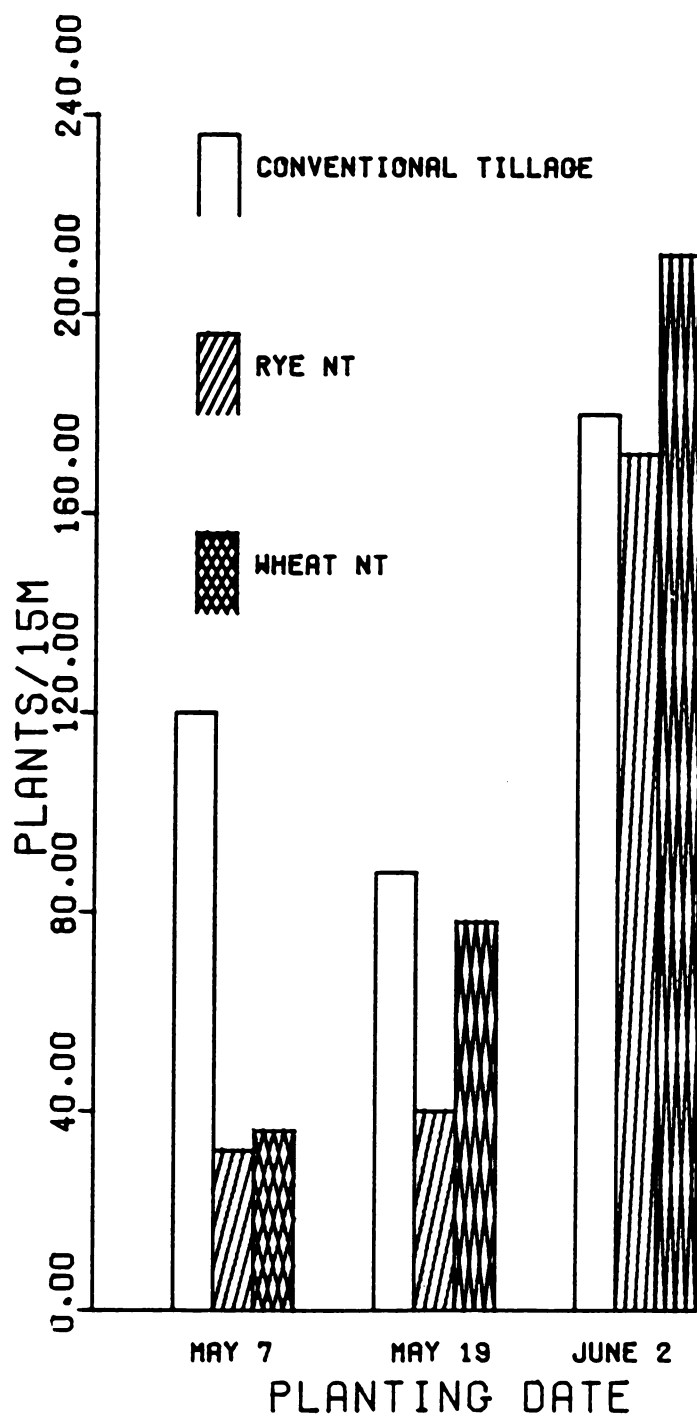




Table 4. The effect of tillage system and planting date on the number of hills per 15 meters, 28 days after planting.

Tillage System	Hills (No./15m) ^x		
	Planting Dates		
	May 7 ^z	May 19 ^z	June 2 ^z
Conventional Tillage	48.4	43.0	56.4
Rye Mulch (NT)	21.0	19.5	54.0
Wheat Mulch (NT)	24.9	39.3	54.9

LSD .05: Between planting dates at the same tillage system, 8.8;
between planting dates at different tillage systems or
the same planting date at different tillage systems, 23.0

^x Each figure is the mean of two seeding methods and four replications.

^z The interaction of tillage system $\times$ seeding method was not significant.

Table 5. The interaction of planting date and seeding method on the emergence of tomato, 28 days after seeding.¹

Planting Date	Emergence (No./15m) ²	
	Seeding Method	
	Raw Seed	Pregerminated Seed
May 7	60.3	67.4
May 19	49.3	89.3
June 2	184.9	187.4

LSD. 05: Between seeding method for same planting date, 20.1;
between seeding method for different planting date, 15.7

¹ Sodus Horticultural Research Farm, 1981.

² Each figure is the mean of three tillage systems and four replications.



seedling emergence for pregerminated seed for the May 19 planting date, but no differences at the other dates. Emergence of tomato increased with subsequent plantings for both seeding methods with highest levels recorded for June 2.

Low stands in early plantings of direct seeded tomatoes were attributed in part to plant destruction by cutworms. Plant stands were reduced in both rye and wheat mulches when compared to conventional tillage (Table 6). Heavier losses were found in rye mulch than in wheat. Musick and Petty (72) observed that in Ohio the black cutworm attacked approximately 15% of seedlings in no-tillage cornfields, whereas in adjacent fields, tilled conventionally, only 1% were attacked. They considered the increased activity to be due to the ovipositional preference of surface trash by the moth and to increased larval survival due to reduced tillage operations. Heavy residue production of the rye and wheat mulches offered ideal conditions for harboring the pest. Rye with its high residue biomass may have offered more cover for larva activity. Although the reduction associated with the presence of cutworms was great, this would not attribute for the total difference between the conventionally tilled and NT plots.

Early stand establishment of direct seeded tomatoes in NT systems were severely reduced. Soil moisture and temperature levels in NT plots did not appear to be limiting factors. Allelopathic leachates from mulch residues has been shown to influence seed germination and emergence (51). Despite these limitations, high plant populations in all plots at the June 2 planting date illustrate that fluid drilling into reduced tillage systems is possible. Patrick (77) noted that



Table 6. Percent stand reduction of direct seeded tomato by cutworms in no-tillage plantings for two planting dates in 1981.^x

Tillage System	Reduction (%) ^y	
	Planting Dates	
	May 7 ^z	May 19 ^z
Conventional Tillage	4.2	3.1
Rye Mulch (NT)	44.1	56.9
Wheat Mulch (NT)	30.2	23.7
LSD .05	34.9	31.2

^xNo damage for June 2 planting date.

^yPercent reduction calculated by dividing the number of damaged plants (P_d) by the sum of the surviving plants (P_s) and the damaged plants (P_d).

$$\% \text{ Reduction} = \left[\frac{P_d}{P_d + P_s} \right] \times 100$$

^zEach value is the mean of two planting methods and four replications.



toxicity of decomposing residues declined as the decomposition period increased, until by the 30th day, little or no phytotoxicity was observed. Late plantings in NT treatments appear to support these findings. Use of pregerminated seeds gave higher plant emergence than did raw seed regardless of tillage system. Under cool soil conditions, rapid emergence and stand establishment are critical, thus sowing pregerminated seeds appear beneficial in achieving this goal.

Effect of Five Fall Sown Cover Crops on Tomato Stand Establishment (1981)

All NT plots had greater emergence of tomato when compared to the conventionally tilled plots (Table 7). Emergence was greatest in the rye cover crop. Heavy rains after planting caused soil crusting in the tilled plots, possibly restricting emergence. Although no residues biomass determinations were made, rye and wheat mulches which appeared to have the heaviest residues also had the highest emergence. This may contribute in part to plant protection from the heavy rains as well as the benefits of improved soil structure associated with no-till soils.

The emergence of pregerminated seeds increased by 10% when compared to the emergence of fluid sown raw seed regardless of the tillage system (Table 8). The emergence of tomato cultivar, Peto 80, was 20% higher than that of UC 82 (Table 9). Differences in the emergence of pregerminated seeds and raw seeds, along with cultivar differences may be important for stand establishment in NT plantings.

The importance of adequate stands for once over harvest and uniform maturity are necessary in direct seeding. Seeding pregerminated seeds can give more reliable stands, with higher plant populations.



Table 7. Effects of six different cropping systems on the emergence of fluid sown tomato.¹

	Emergence ²
	No./10.5m
Conventional Tillage	49.9 d
Rye Mulch (NT)	153.2 a
Wheat Mulch (NT)	120.6 b
Oat Mulch (NT)	99.9 bc
Sunflower Mulch (NT)	99.6 bc
Ryegrass Mulch (NT)	76.6 c

¹ Means followed by the same letter are not significantly different at the 5% level by DMR.

² Each figure is the mean of two seeding methods, two cultivars and four replications.



Table 8. Effect of seeding method on the emergence of fluid sown tomato in no-till plots.¹

Seeding Method	Emergence
	No./10.5m
Raw Seed	88.6 a
Pregerminated Seed	104.9 b

¹Means followed by same letter are not significantly different at the 5% level

Table 9. Effect of different cultivars on the emergence of fluid sown tomato in a no-till system.¹

Cultivar	Emergence
	No./10.5m
UC 82	88.6 a
PETO 80	110.2 b

¹Means followed by same letter are not significantly different at the 5% level



Combining this seeding technique with NT soil management systems may result in the high plant populations necessary for field seeded tomato.

Effect of Rye and Wheat on Early Planted Tomato and Weeds (1982)

Tomato emergence was significantly greater in the rye mulch than either the conventional tillage or wheat mulch plots for the May 8 planting date (Figure 10). At the May 27 planting date, there was a significant interaction between the tillage system and seeding methods (Table 10). Total emergence for the rye and wheat mulched plots increased by 45 and 62%, respectively, when pregerminated seeds were sown instead of raw seed. In the CT plots, raw seeds emerged better than pregerminated seeds. There were 9.1 and 10.2 hills per row in the rye mulch for the May 8 and May 27 planting dates, respectively, which was significantly more than either the wheat mulch or conventionally tilled treatments (Table 11). There were no differences between the CT and wheat NT plots for either planting date.

The time to 50% emergence (T50) for pregerminated seed was less than for raw seed regardless of tillage system (Table 12). The emergence of pregerminated seeds was 3.8 and 3.0 days faster when sown in rye and wheat mulch, respectively, than when sown in CT plots. There were no differences in emergence times for raw sown seed in NT or CT treatments.

Population densities and biomass of redroot pigweed were significantly greater in the tilled plots when compared to the NT plots (Table 13). The number and weight were reduced by 96 and 88% respectively, in the rye mulch. Wheat mulch reduced the population and biomass of redroot pigweed by 92 and 80%. There were no

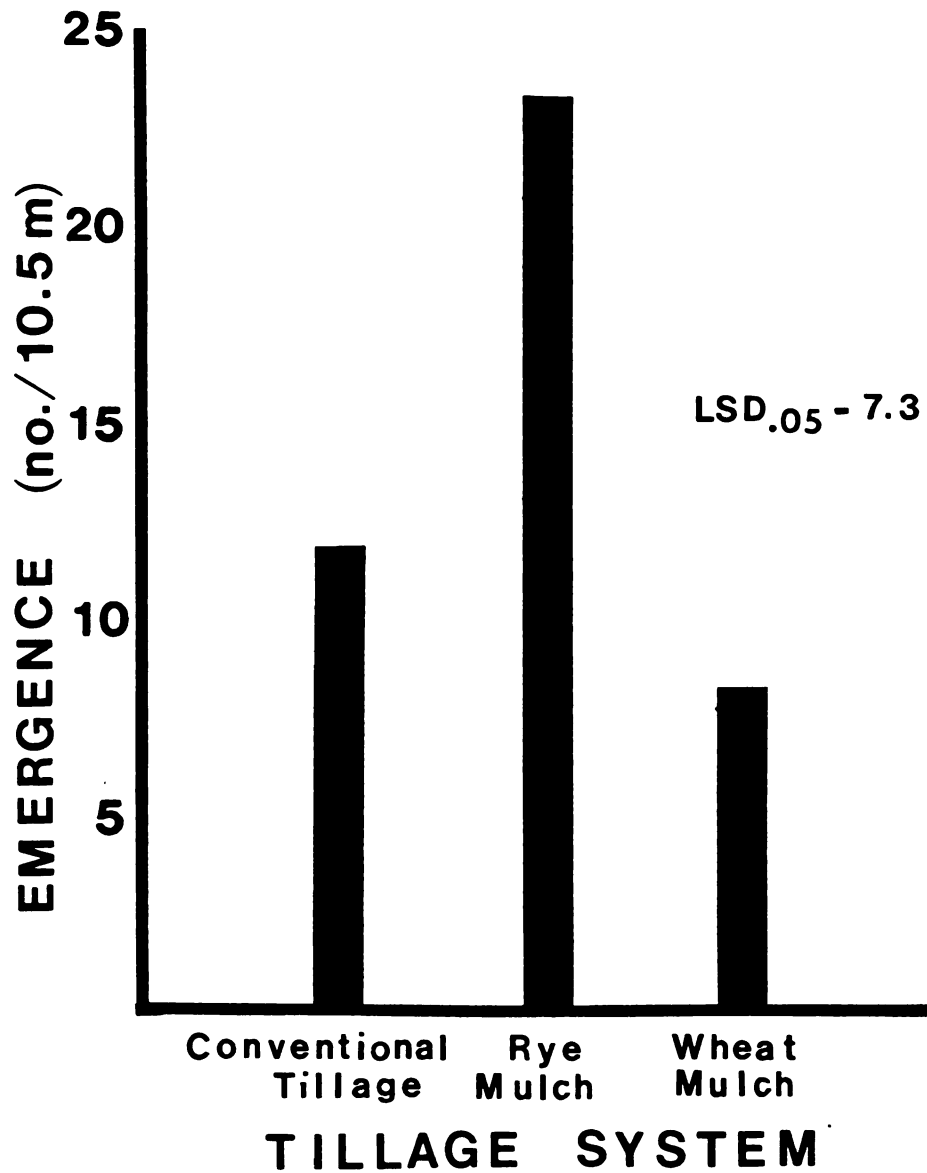


Figure 10. The effect of tillage system on the emergence of tomato sown in a Marlette fine sandy loam. Values are the means of two planting methods and six replications.

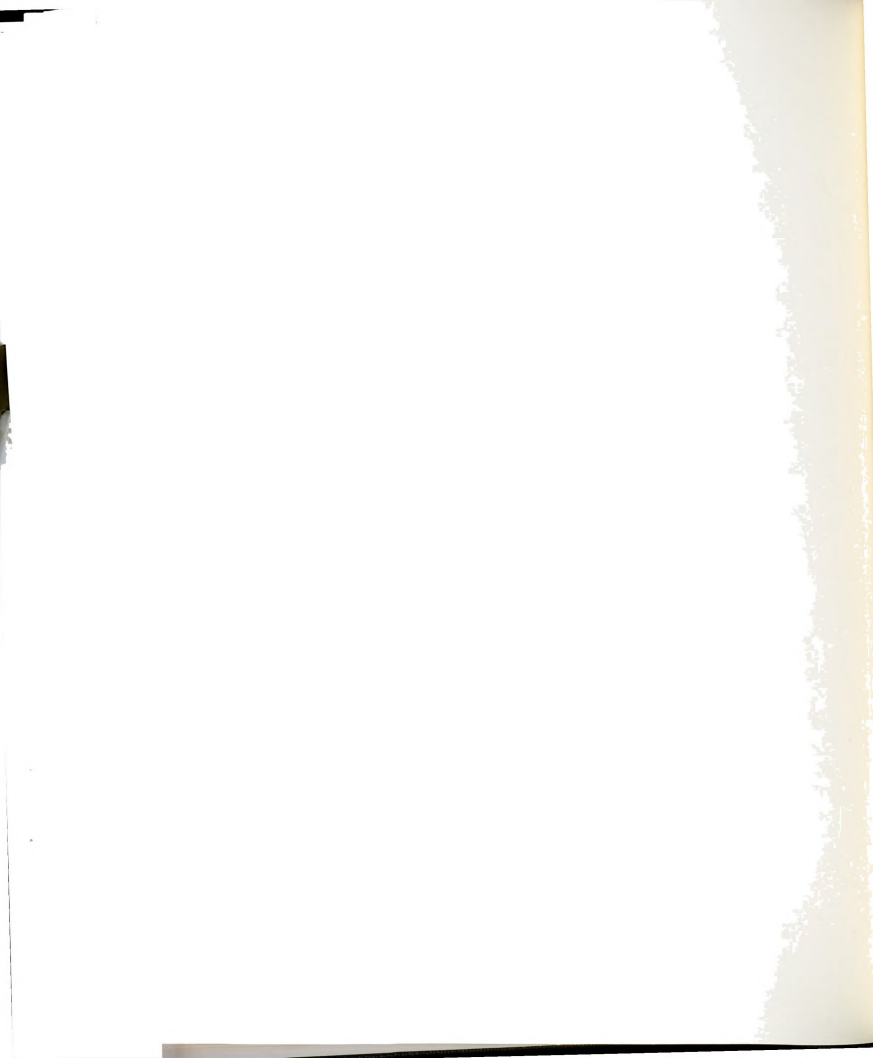


Table 10. The interaction of tillage system and seeding method on the total emergence of tomato planted on May 27, 1982.

Tillage System	Emergence No./10.5m	
	Seeding Method	
	Raw Seed	Pregerminated Seed
Conventionally Tilled	15.8	9.5
Rye Mulch (NT)	19.0	34.5
Wheat Mulch (NT)	5.8	13.2

LSD .05: Between seeding methods for the same tillage system, 11.1; between seeding methods for different tillage systems, 8.8.

Table 11. The effects of tillage systems on the number of hills of tomato per 10.5 meters of row at two planting date in 1982.¹

Tillage System	Hills/10.5m	
	Planting Dates	
	May 8	May 27
Conventional Tillage	4.3 a	4.8 a
Rye Mulch (NT)	9.1 b	10.2 b
Wheat Mulch (NT)	4.2 a	3.8 a

¹ Means in columns followed by the same letter are not significantly different at the 5% level by DMR.



Table 12. The effect of tillage system and seeding method on the time to 50% emergence (T50) of fluid sown tomato seed in 1982.

Tillage System	T50 Emergence (days) ¹	
	Seeding Method	
	Raw Seed	Pregerminated Seed
Conventional Tillage	12.4	10.3
Rye Mulch (NT)	11.6	6.5
Wheat Mulch (NT)	11.8	7.3

LSD .05: Between seeding methods for the same tillage system, 1.2; between seeding methods a different tillage systems, .8

¹Each figure is the mean of two planting dates and six replications. The interaction of seeding method x planting date and tillage system x planting date was not significant.

differences in population or weight of large crabgrass in any of the tillage systems (Table 13).

Tomato seed respond well to pregermination and fluid drilling into rye cover crops by increased emergence, number of hills and reduced T50. Although economical stands were not achieved in any of the plantings, the benefits of pregermination and fluid drilling in a no-tillage system were illustrated. The low number of hills per row is a better indicator of the poor stand than the total emergence.

Dry soil conditions at planting in the conventionally tilled plots and wheat mulch were major limiting factors influencing stand. Soil moisture levels were lowest in the seed zone (0-7.5 cm) particularly at the early planting date (Figure 6). Soils in the tilled plots were dry and fluffy in early May. Rainfall was 4.7 cm for the month, 3.1 cm below normal. Seed placement may have been deeper than recommended for tomato, thus adversely affecting emergence. Lower emergence levels with pregerminated seed in the conventional tilled plots could have been associated with the dry, fluffy soil condition and deep seed placement. Dry soil may draw the moisture stored in the gel away from the germinated seed. This would expose the radicle to conditions that allow it to dessicate before adequate root to soil contact was achieved or rainfall replenished soil moisture levels. In a year of dry soil conditions with minimal rainfall, retention of plant residues on the soil surface may conserve soil moisture, thus improving stands. Careful management of cover crops under dry conditions is necessary because living cover crops extract stored soil moisture. This may be beneficial in a year of high rainfall, but posed a problem in this experiment.



Table 13. The effects of tillage system on weed densities and biomass per 1m² of redroot pigweed and large crabgrass in a Marlette fine sandy loam.¹

Tillage System	Redroot Pigweed		Large Crabgrass	
	No./m ²	(g)/m ²	No./m ²	(g)/m ²
Conventional Tillage	17.0 b	29.7 b	21.3 a	24.3 a
Rye Mulch (NT)	0.7 a	3.6 a	19.5 a	37.0 a
Wheat Mulch (NT)	1.3 a	6.0 a	17.8 a	38.0 a

¹Means followed by the same letter are not significantly different at the 5% level with DMR

The effects of rye and wheat mulches on redroot pigweed populations and biomass reductions confirms previous reports of benefits of these cover crops in weed control (7). Poor weed control in the CT plots may be due to continual exposure of weed seeds to the soil surface where they can germinate. Faulkner suggested that fall seeded rye be put into the land in the spring before weeds bloom (35). After a few years, weed pressure would be reduced by exhausting the weed seeds in the top soil. This would reduce annual weeds in the NT crop production system. Allelopathic compounds found in residues of rye and wheat may have contributed to the weed reduction in the no-tillage plots.

Large crabgrass populations and biomass under no-tillage soil management systems were not different from CT. Other studies indicate that annual grasses may be a worse problem in NT (26). The weed pressure in all plots was too great to see differences in this first year of cropping. It is possible that after a few years, populations will be decreased in NT plots. It is also possible that the allelopathic compounds in rye and wheat do not influence the germination and growth of large crabgrass. Further studies in this area need to be undertaken to address this problem.

Effect of Rye Mulch on Late Planted Tomatoes and Weeds (1982)

Although there were no difference in final stand, seedlings did emerge faster in the rye mulch than under CT (Table 14). Final stands of tomato sown from pregerminated or raw seeds were not significantly different, however, the speed of emergence was two days faster for pregerminated seeds than raw seed (Table 15).



Table 14. Effect of tillage treatment on emergence, hills and T50 emergence of tomato seeded June 2, 1982.¹

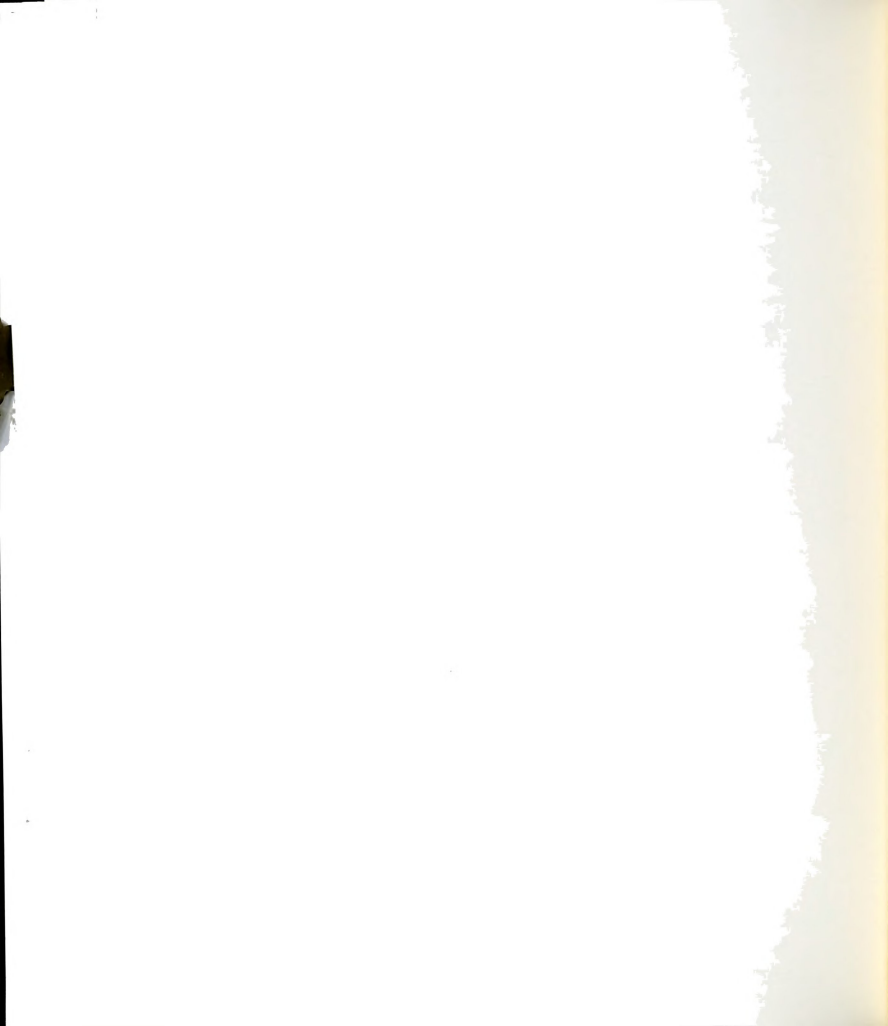
Tillage Treatment	Emergence	Hills	T50
	No./7.6m	No./7.6m	days
Conventional Tillage (CT)	60.8 a	18.2 a	8.9 a
Rye Mulch (NT)	75.8 a	21.2 a	8.3 b

¹Means followed by same letter are not significantly different at the 5% level

Table 15. Effect of seeding methods on emergence, hills and T50 emergence of tomato sown on June 2, 1982.¹

Seeding Method	Emergence	Hills	T50
	No./7.6m	No./7.6m	days
Raw Seed	72.3 a	19.8 a	9.6 a
Pregerminated Seed	63.5 a	19.5 a	7.6 b

¹Means followed by same letter are not significantly different at the 5% level



Late plantings of tomato, whether from pregerminated or raw seed, emerged well in rye residues. Emergence is still faster with pregerminated seeds, but total number of plants is not different from raw seed. The benefits of pregermination are not as great as seen under suboptimal growing conditions. The benefits of rye mulch are still obvious as seen with increased number and hills of tomato. Plots with rye mulch appeared to have more moisture available which may have helped increase emergence.

Weed populations of redroot pigweed and large crabgrass were reduced by 98 and 71%, respectively in the rye mulch (Table 16). Biomass of redroot pigweed was reduced by 96% under rye residues, however, there was no difference for large crabgrass.

Heavy rye residues appear beneficial in reducing weed populations of redroot pigweed and large crabgrass. Controlling certain broadleaf weed species by cover crop residues is an added benefit to NT plantings and suggests that allelopathy may be involved in weed control. It is also possible that by not disturbing the soil surface, new weed seeds were not exposed to conditions favorable for germination. Further studies of grass weed problems need to be investigated before full implementation of NT production systems can be fully recommended.

CONCLUSIONS

Soil temperatures responded similarly in both years. There was no difference between conventional tillage and rye and wheat mulches in either year. Temperatures were always highest near the soil surface (5 cm depth) and were near optimum for tomato seed germination at each planting. Soil moisture levels were consistently higher in the wheat



Table 16. The effect of tillage system on the density and biomass per lm^2 of redroot pigweed and large crabgrass.¹

Tillage System	Redroot Pigweed		Large Crabgrass	
	No./m ²	(g)/m ²	No./m ²	(g)/m ²
Conventionally Tilled	133.3 b	34.7 b	86.0 b	11.1 a
Rye Mulch (NT)	3.3 a	1.4 a	17.0 a	5.2 a

¹Mean followed by same letter not significantly different at the 5% level



mulch when compared to the conventionally tilled. Moisture levels in the rye mulch were higher in only one year. Low moisture levels near the surface in all tillage systems may have influenced stand establishment. Higher moisture levels deeper in the soil profile could be important for maintaining plant growth during moisture stress periods later in the growing season. Fall sown cover crops provide soil protection during the winter and allow access to field seeding during unfavorable spring conditions. Soil moisture conservation with a surface mulch can be beneficial during periods of stress. In dry years moisture conserved by surface mulches may contribute to increased stands in NT planting.

In three of the four experiments, stands of NT direct seeded tomatoes were as good or better than those in conventionally tilled plots. Stands were generally better in rye mulch when compared with wheat mulches. Higher plant stands suggest that the use of NT planting of direct seeded tomatoes can be successfully managed. Use of pregerminated seeds resulted in higher plant populations, more hills and reduced emergence time (T50) than raw seed. Early season plantings benefited more from pregerminated seed than later plantings. Combining pregermination and NT practices appears to be a feasible means of stand establishment. Problems with emergence in sub-optimal temperatures associated with NT plantings can be partially overcome by fluid drilling. Plant residues of rye or wheat not only protect young seedlings, but suppress weed growth. Use of cover crops to control weeds is an added benefit to stand establishment in NT plantings.



THE INFLUENCE OF TILLAGE SYSTEM, SEEDING METHOD
AND PLANTING DATE ON THE GROWTH AND
YIELD OF PROCESSING TOMATOES

Abstract

Two fall seeded cover crops were evaluated for their effects on plant growth and yield of tomato in no-tillage plantings. Tomatoes were either direct seeded or transplanted into existing residues at three different planting dates in 1981. Growth of transplants was not influenced by the different tillage systems, however, flowering was delayed in tomatoes planted on June 2. Early growth of direct seeded tomatoes was reduced and flowering delayed when planted in rye or wheat residues. While plants from pregerminated seeds in conventionally tilled plots developed more flowers when compared to raw seed, there were no differences between the two direct seeding methods in no-tillage treatments. Yields of tomato were reduced by 38 and 24% in the rye and wheat mulch, respectively, when compared to the conventional tillage. Yields of transplants were highest when planted by May 7, and decreased with later plantings. Total yield of ripe fruits was lower for fluid sown raw seed than either pregerminated seeds or transplants. Average number of fruits per plant was greater with the transplanted tomatoes, but average fruit weight was less than with either direct seeding method. Ripening and rotting patterns for all tillage treatments and seeding methods were similiar.



CHAPTER 3

THE INFLUENCE OF TILLAGE SYSTEM, SEEDING METHOD AND PLANTING DATE ON THE GROWTH AND YIELD OF PROCESSING TOMATOES

Introduction

No-tillage (NT) practices have been used in certain agronomic and horticultural crops to reduce erosion and labor, plus conserve soil moisture. The effects of NT on the yield potential of vegetable crops compared to conventional tillage (CT), however, has not been thoroughly studied. The yield of those crops grown in a reduced tillage system will depend on the effects of the soil environment on plant growth.

Unger (102) reported that the soil temperature under 8 or 12 metric tons/acre of wheat (Triticum aestivum L.) straw was up to 3°C below the optimum for the germination of sorghum (Sorghum bicolor L.). These cooler temperatures delayed seed germination and slowed early plant growth. Moody et al (68) indicated that a surface mulch of 3 tons/acre of wheat straw temporarily retarded the early season growth of corn (Zea mays L.), however, the overall growth and yield were benefited by mulching. Van Wijk et al. (102) and Larson et al. (60) have shown that soil temperature differences at the seed depth in NT plantings influence early plant growth in the northern corn belt. Early planting of tomatoes is advantageous for obtaining maximum yields where growing seasons are limited. Since conservation tillage has been shown



to decrease soil temperatures, it is a major concern in the adaption of this technology to tomato production.

Hovermale found that soybeans (Glycine max L.) grew taller and branched higher when grown in 2x rates of mulch that was at least 35 cm tall (55). Lodging increased with increased amounts of mulch, however, grain yields were not affected by mulch rates. Kaul and Sekhon reported higher plant populations in mulched plots which resulted in increased soybean grain yield (57). Applications of wheat straw did not increase the number of pods/plot, seeds/pod or grain weight, but did increase plant height.

Increases in the yields of vegetables with reduced tillage practices have been reported by Beste (7). He noted the response of several vegetables to herbicides for NT culture and found that the yield of direct seeded NT tomatoes (Lycopersicum esculentum Mill.) were equal to those of CT crops. Grenoble (49) reported direct seeded tomatoes were adversely affected by NT soil management practices. Yields were 4.4 and 18.8 tons/acre, respectively, for NT and CT plots. Morse (69) noted a yield increase of 200 cwt/acre when transplanting tomatoes in NT plots as compared to CT practices. Yield differences were attributed to increased fruit numbers per plant rather than increase of fruit size.

No-tillage processing tomato production is a relatively new concept, and the effects of surface residues on plant development and yield is not known. The objective of this research was to study the effects of rye and wheat cover crops on the growth characteristics and yield of direct seeded and transplanted tomatoes.



MATERIALS AND METHODS

Tomatoes (cv. UC 82) were field grown with different tillage treatments, seeding methods and planting dates in 1981, on an Oshtemo sandy loam soil at the Sodus Horticulture Research Farm, Sodus, Michigan. Tillage treatments included conventional tillage (CT), rye mulch (NT) and wheat mulch (NT); seeding methods were raw and pregerminated seeds fluid drilled and transplants. Tomatoes were planted on May 7, May 19 and June 2.

On September 22, 1980, two cover crops, rye (Secale cereale L. cv. Wheeler) and wheat (cv. Tecumseh) were planted with a Moore-Uni-Drill. Seeds were planted to a depth of 2.5 cm in plots 15 x 18 meters. There were four replications. Potash (224 kg/ha) and Ammonium Nitrate (56 kg/ha) were broadcast over all plots and incorporated prior to seeding. The conventionally tilled plot was also planted with rye.

Paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) was applied to the rye and wheat NT plots on April 27, 1981 at a rate of 1.1 kg/ha. The CT plot was disked once to knock down the standing rye, plowed and then disked again. Napropamide (2-(α -naphthoxy)-N,n-diethylpropionamide) (1.1 kg/ha) was applied to the control plots and incorporated prior to planting tomatoes.

Dry and pregerminated tomato seeds were sown in the field with a tractor mounted fluid drill on May 8, May 19 and June 2, 1981. Seeds were pregerminated by suspending them in cheese cloth bags for 72 hours in an aerated water bath. The seeds were mixed with a fluid carrier (Vittera II, 1.5% w/v solution) just before sowing. The gel/seed mixture was extruded at a rate of 4-6 ml of gel spaced every 25 cm.



There were approximately 3-6 seeds in each gel clump. Seeding rate and depth were 560 g/ha and 20 mm, respectively. Row spacing was 1.5 meters.

Transplants were raised in 6 x 27 x 54 cm flats for four weeks prior to field planting. Flats were sown with seeds that had been germinated for 72 hours at 25°C, with radicles 1-3 mm in length. There were approximately 80 plants per flat. Bare root transplants were hand planted at 30 cm intervals with 250 ml of liquid starter fertilizer (Peters 20-20-20, 3.9 g/liter) applied to each plant.

Soil temperature was monitored with an integrated circuit temperature sensor and standard voltage meter. In each cover crop temperature was measured daily at 8:00 am, 12:00 pm and 5:00 pm at depths of 5, 15 and 24 cm starting May 18. Data was analyzed to obtain daily temperature averages for the various tillage systems and depths. There were three replications. Daily average temperature values for the 5 cm depth were converted to heat units, base 10.

Metribuzin (4-amino-6-tert-butyl-3(methylthio)-s-triazine-5(4H)) was applied at a rate of .37 Kg/ha on July 2 for broadleaf weed control. Fungicides and insecticides were applied as recommended for control of plant diseases and insects. Ammonium Nitrate (56 kg/ha) was side-dressed by all treatments on July 8.

Plant Growth of Transplants and Direct Seeded Tomatoes

Data on plant growth was collected at two week intervals starting on June 16. Measurements taken during the growing season included (i) average plant height, (ii) dry weight, (iii) number of flower clusters, (iv) number of open flowers and (v) closed flowers. There



were a total of five sampling dates for the direct seeded tomatoes and six for the transplants. A 1.5 meter section of row was harvested and five randomly selected plants measured for the direct drilled treatments. Measurements were taken on all four replications. Five consecutive plants were evaluated in the transplanted rows. There were three replications sampled. All data was analyzed by analysis of variance.

Yield of Ripe and Rotted Fruits

Yields of both ripe and rotted fruits were harvested at weekly intervals from individual 1.5 meter sections of row. Use of a repeated cumulative harvest for both ripe and rotted sub-plots supplied a method where by the development of ripe and rotted fruit could be traced throughout the growing season. Use of this method allowed frequent harvests that took into account environmental effects as well as ripening differences between treatments. This system was described by MacNab and Pennypacker (66) and was used to evaluate the control of fruit rot in single-harvest tomatoes. The system allows for unlimited harvest dates and repeated use of the same harvest space. A destructive harvest method would require as many subplots per treatment replication as there were harvest days. Harvest began on August 22 and continued through November 1. Only fruits that were visibly diseased or cracked were harvested from the section of row designated for rotten fruits. All fruits were counted and weighed. Total number and weight were calculated by adding all harvest dates. All results were analyzed by analysis of variance.



RESULTS

Plant Growth of Transplants and Direct Seeded Tomatoes

The number of flower clusters on transplanted tomatoes grown in the two NT treatments on June 18 was lower than in the CT plots (Table 1). There was no significant difference between tillage systems for plant height, number of open and/or closed flowers until the final sampling date. At that time, the rye NT treatment had fewer closed flowers than the conventionally tilled. The interaction of tillage system and planting date was not significant for plant height, number of opened and/or closed flowers or flower clusters, for any of the sampling dates.

Late season transplanting (June 2) decreased plant height at the second sampling date but had no effect thereafter (Table 2). The number of open and closed flowers and flower clusters varied in response to planting date (Table 2). Early transplants had greater numbers of flower clusters throughout the growing season as compared to later plantings. Number of open and closed flowers increased rapidly from the first sampling period and then gradually declined. Differences between the treatments and the various sampling dates were due primarily to differences in plant age.

There was a significant interaction between tillage treatments and planting dates on plant height and dry weight of direct seeded tomato for June 16, July 2, and July 16 sampling dates (Table 3a). Plant height in CT plots decreased with later planting dates. Trends were similar for both NT plots, however, residues of rye suppressed plant height more than either CT or wheat mulch for the May 19 planting date. There were few differences for the later sampling dates.

Table 1. The effect of tillage system on plant height, number of flower clusters and number of open and closed flowers of transplanted tomatoes at six different sampling dates in 1981.

Tillage System	Sampling Dates					
	June 18	July 2	July 16	July 30	Aug. 13	Aug. 27
<u>Plant Height (cm)</u>						
Conventional Tillage	44.9	49.7	55.7	58.6	61.9	68.6
Rye Mulch (NT)	46.7	47.9	56.5	58.8	61.0	64.5
Wheat Mulch (NT)	40.7	43.9	52.2	56.4	63.7	70.6
LSD .05	NS	NS	NS	NS	NS	NS
<u>Flower Clusters (No.)</u>						
Conventional Tillage	11.1	17.8	22.4	27.1	32.9	44.1
Rye Mulch (NT)	6.4	14.1	20.9	21.7	22.8	29.3
Wheat Mulch (NT)	6.1	11.5	18.2	23.6	27.4	34.9
LSD .05	3.5	NS	NS	NS	NS	NS
<u>Open Flowers (No.)</u>						
Conventional Tillage	17.1	28.9	22.3	19.4	17.5	50.5
Rye Mulch (NT)	10.3	19.8	18.3	15.0	13.6	19.7
Wheat Mulch (NT)	13.0	13.8	19.1	15.4	21.0	39.7
LSD .05	NS	NS	NS	NS	NS	NS
<u>Closed Flowers (No.)</u>						
Conventional Tillage	24.4	32.4	17.4	13.5	17.7	27.0
Rye Mulch (NT)	15.1	24.4	17.7	6.5	8.1	5.5
Wheat Mulch (NT)	17.1	18.9	16.1	12.0	12.3	15.5
LSB .05	NS	NS	NS	NS	NS	15.9



Table 2. Effect of planting date on plant height, flower cluster and open and closed flowers of transplanted tomatoes at six different sampling dates in 1981.

Planting Date	<u>Sampling Dates</u>					
	June 18	July 2	July 16	July 30	Aug. 13	Aug. 27
<u>Plant Height (cm)</u>						
May 7	45.3	54.3	56.9	57.8	62.0	70.4
May 19	42.9	53.7	53.6	55.7	58.3	--
June 2	--	33.8	54.2	60.3	66.4	65.6
LSD .05	NS	5.2	NS	NS	NS	NS
<u>Flower Clusters (No.)</u>						
May 7	7.9	19.5	20.1	24.7	31.5	46.8
May 19	7.9	20.1	25.0	20.1	27.0	--
June 2	--	3.8	16.4	25.5	24.6	25.4
LSD .05	NS	5.3	5.6	NS	4.6	8.4
<u>Open Flowers (No.)</u>						
May 7	12.6	26.4	15.8	11.7	18.4	16.1
May 19	14.4	30.9	18.6	11.2	13.7	--
June 2	--	5.3	25.2	26.9	19.4	17.1
LSD .05	NS	9.3	NS	7.3	NS	NS
<u>Closed Flowers (No.)</u>						
May 7	19.8	28.6	8.2	6.9	12.5	26.1
May 19	18.0	32.3	10.8	3.1	14.5	--
June 2	--	14.9	32.2	22.0	11.1	6.0
LSD .05	NS	NS	8.9	NS	NS	12.3



Table 3. The interaction of tillage system and planting date on plant height and dry weight of direct seeded tomatoes during 1981.

Tillage System	Planting Date	Sampling Dates			
		June 18	July 2	July 16	July 30 Aug. 27
a) Plant Height					
Conventional Tillage	May 7	15.0	34.8	52.7	57.2
	May 19	11.5	15.4	45.3	63.0
	June 2	--	15.7	31.5	53.8
Rye Mulch (NT)	May 7	13.3	25.0	37.8	44.8
	May 19	9.6	15.4	19.4	39.1
	June 2	--	15.7	32.1	59.4
Wheat Mulch (NT)	May 7	14.3	19.8	35.9	54.4
	May 19	13.6	26.2	45.3	64.9
	June 2	--	15.0	33.8	57.7
	LSD .05	2.9	12.5	14.9	NS
b) Dry Weight					
Conventional Tillage	May 7	3.7	15.9	76.3	115.4
	May 19	1.7	13.0	52.3	113.7
	June 2	--	1.3	11.7	66.5
Rye Mulch (NT)	May 7	1.9	5.3	29.6	38.5
	May 19	.7	2.5	8.6	40.6
	June 2	--	1.2	8.7	46.7
Wheat Mulch (NT)	May 7	.8	5.2	24.1	67.7
	May 19	1.7	5.3	21.7	105.1
	June 2	--	1.2	9.6	48.3
	LSD .05	1.2	7.3	38.3	NS



Plant dry weight decreased for all tillage treatments with later plantings (Table 3b). Differences between early (May 7) and late (June 2) plantings were greatest in the CT plots, with fewest differences seen in the NT treatments. Plant dry weight for the late planted tomatoes were not different from each other in any of the tillage systems. Growth for all planting dates and tillage systems were similar by July 30.

Tomatoes planted on May 7 and May 19 in CT plots had significantly greater numbers of flowers and flower clusters when compared to either NT treatment (Table 4). There was no difference between tillage systems in the number of flowers and flower clusters when planted on June 2. Plants established with pregerminated seeds had more flowers and flower clusters than plants from raw seed, regardless of planting date or tillage system (Table 5 and Table 6). Differences between raw and pregerminated seeds were greatest when planted by May 7 or grown in CT treatments. There was no difference between the two seeding methods when planted on May 19 or June 2 (Table 5). Similarly the flowering of plants grown from raw and pregerminated seeds were not significantly different when grown in either rye or wheat mulches (Table 6).

Soil heat unit accumulation in the seeding zone (5 cm) and plant height for all tillage systems were positively correlated (Figure 1). The coefficient of correlation (r) for the conventional tillage, rye mulch (NT) and wheat mulch (NT) were $r=.94$, $r=.94$ and $r=.96$, respectively. There was a positive correlation between soil heat units and plant dry weight for all tillage treatments (Figure 2).



Table 4. Effect of tillage system and seeding date on average number of flowers and flower clusters (July 2, 1981)

Tillage System	Seeding Date	Flower Clusters (No.)	Flowers (No.)	
			Open	Closed
Conventional Tillage	May 7	3.3	3.0	13.4
	May 19	3.3	2.0	14.5
	June 2	0.1	0.0	0.4
Rye Mulch (NT)	May 7	1.6	0.9	6.9
	May 19	0.6	0.1	3.1
	June 2	0.1	0.0	0.4
Wheat Mulch (NT)	May 7	1.2	0.9	4.1
	May 19	1.1	0.4	4.5
	June 2	0.2	0.0	1.2
	LSD .05	1.5	1.5	7.6

Table 5. Effect of planting date and seeding method on the number of flowers and flower clusters of tomato. (July 2, 1981)

Planting Date	Seeding Method	Flower Clusters (No.)	Flowers (No.)	
			Open	Closed
May 7	Raw Seed	1.0	0.5	4.1
	Pregerminated Seed	2.6	2.4	10.5
May 19	Raw Seed	1.4	0.8	6.1
	Pregerminated Seed	2.2	1.3	9.0
June 2	Raw Seed	0.0	0.0	0.1
	Pregerminated Seed	0.2	0.0	0.8
	LSD .05	1.5	1.5	7.6



Table 6. Effect of tillage system and seeding method on the number of flower and flower clusters of direct seeded tomatoes. (July 2, 1981)

Tillage System	Seeding Method	Flower Clusters (No.)	Flowers (No.)	
			Open	Closed
Conventional Tillage	Raw Seed	1.2	0.5	5.4
	Pregerminated Seed	3.2	2.8	13.4
Rye Mulch (NT)	Raw Seed	0.6	0.2	2.8
	Pregerminated Seed	0.9	0.4	4.1
Wheat Mulch (NT)	Raw Seed	0.8	0.5	3.1
	Pregerminated Seed	0.9	0.6	3.4
	LSD .05	1.5	1.5	7.6



Figure 1. The relationship of accumulated heat units and plant height of tomato grown in three tillage systems. Tomatoes were planted on May 19, 1982. Heat units were calculated from mean daily soil temperatures taken at the 5 cm depth and converted to heat units base 10.

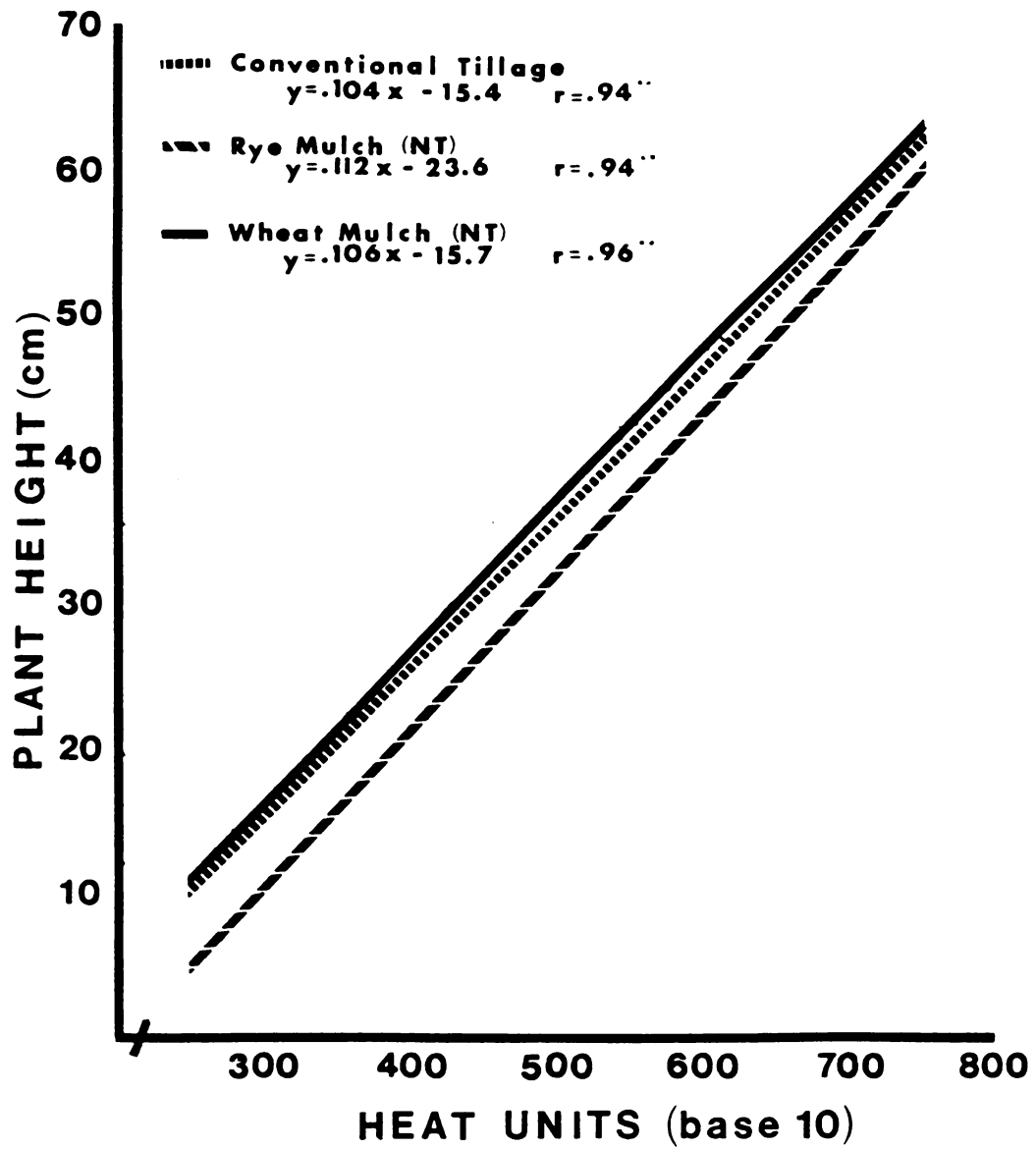
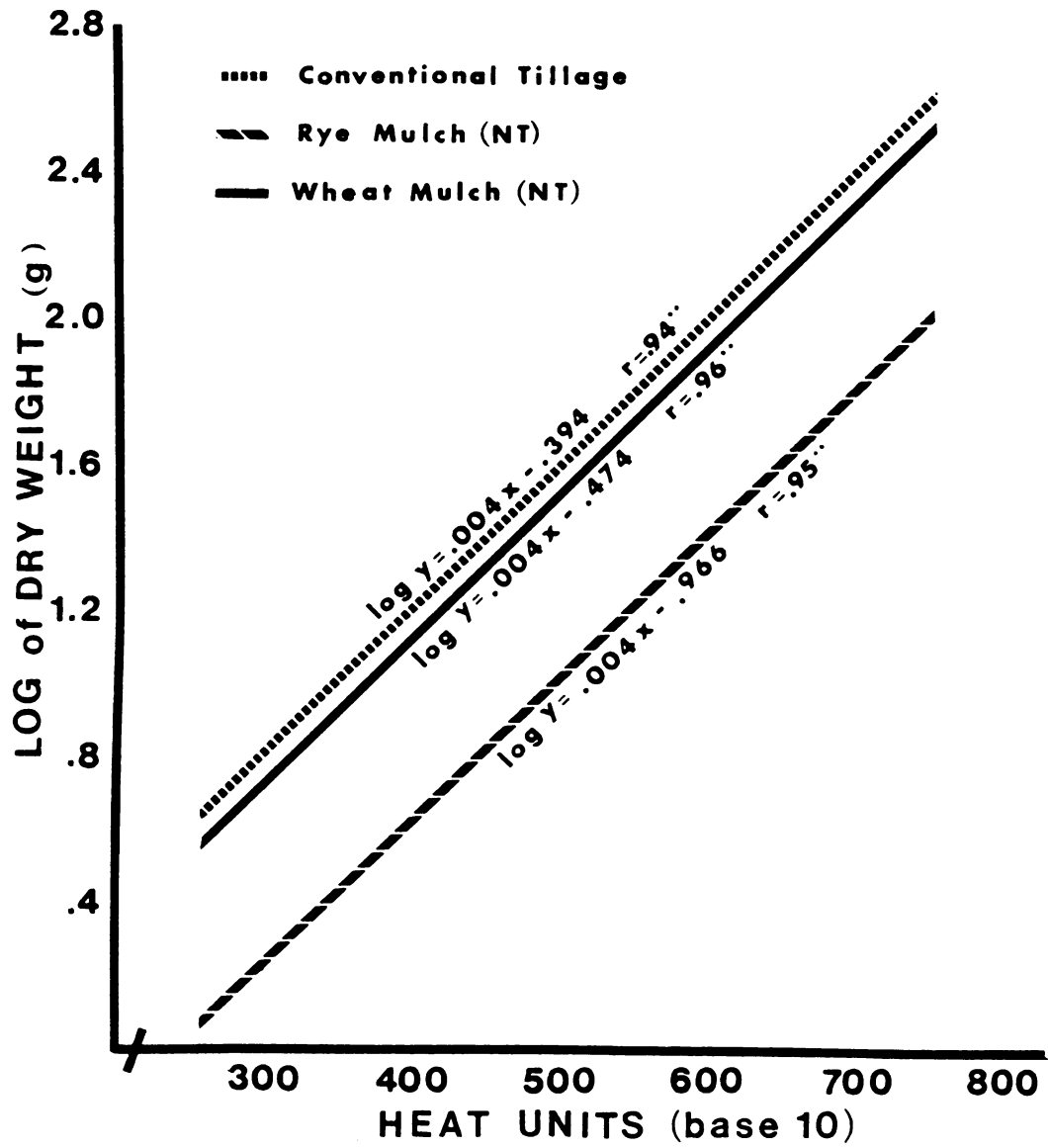




Figure 2. The relationship of dry weight of tomato and accumulated heat units when grown in three tillage systems. Tomatoes were planted on May 19, 1981. Heat units were calculated from daily mean soil temperatures taken at the 5 cm depth and converted to heat units base 10. Data was transformed with logarithm transformation.





Yield of Ripe and Rotted Fruits

Total number and weight of ripe fruits was significantly higher in the CT plots than either the rye or wheat NT plots (Table 7). The number of ripe fruits was reduced by 44 and 27% for the rye and wheat NT plots, respectively, when compared to the CT. Similiar reduction in fruit weight was noted for the NT treatments. There were no differences, however, between average weight per fruit in any of the tillage treatments.

Tomatoes transplanted by May 7 had significantly greater yields than either fluid sown pregerminated seed or raw seed (Figure 3). Yields decreased linearly for the transplanted crop with later planting date. There was no difference in the total weight of fruits harvested at either the May 7 or May 19 planting dates for tomatoes grown from pregerminated seeds, however, there was a substantial yield increase for those planted on June 2. Total yield of ripe fruits was lower for the May 19 planting date for plants grown from raw seed. The interaction of tillage system x planting date or seeding method was not significant.

Total yield in MT/ha was consistently higher in the CT plots when compared to either NT plot for any planting date (Table 8). There were no differences between either NT treatment, however, the yield of tomatoes grown in the rye mulch was significantly less than the CT for either May planting date. Highest yields were recorded with early planting in CT plots.

The average weight per fruit was significantly affected by planting date and seeding method (Table 9). Fruit harvested from direct seeded plantings for May 7 and May 19 weighed more than those planted on June 2.



Table 7. Total number, weight and average weight of ripe tomato fruits as influenced by tillage system.

Tillage System	Ripe Fruits (No.)/1.5 m	Weight (MT/ha)	Weight (g)/Fruit
Conventional Tillage	318.1 ^x	11.1	49.6
Rye Mulch (NT)	178.8	6.8	53.9
Wheat Mulch (NT)	230.7	8.4	51.8
LSD .05	49.6	2.2	NS

^x Interaction of tillage system x seeding date and tillage system x seeding method not significant for the total number of fruits harvested.

Table 8. Tomato yields as influenced by tillage system and planting date.

Tillage System	Yield (MT/ha)		
	Planting Dates		
	May 7	May 19	June 2
Conventional Tillage	13.1	10.2	10.1
Rye Mulch (NT)	6.5	5.6	8.3
Wheat Mulch (NT)	8.8	8.3	8.2

LSD .05: Between tillage system and planting date; 4.4



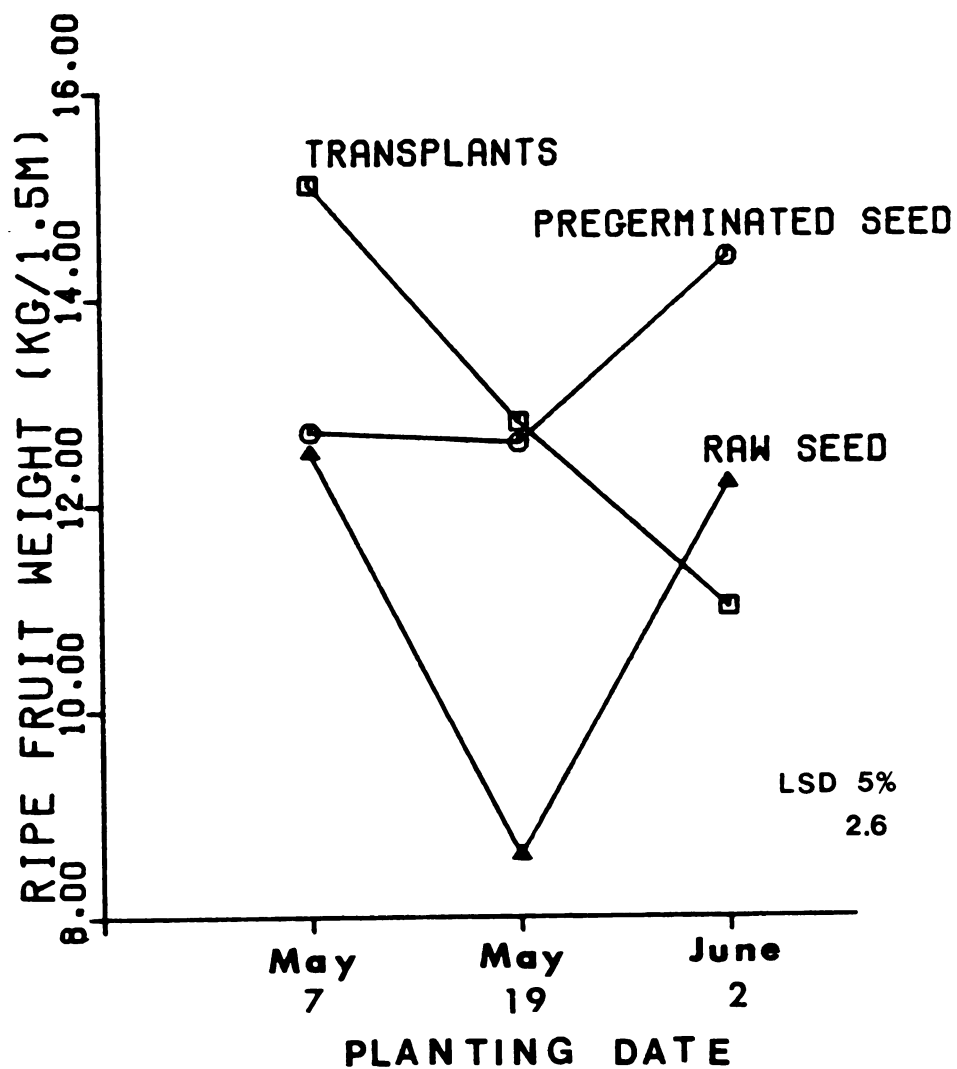


Figure 3. Effect of seeding method and planting date on the total weight of ripe fruit harvested from 1.5 meter rows. Values are the average of three different tillage systems.



Table 9. Average weight of fruits per plant as influenced by seeding method and planting date.

Seeding Method	Planting Dates		
	May 7	May 19	June 2
	<u>Fruit Weight (g)</u>		
Raw Seed	55.7	58.4	50.1
Pregerminated Seed	53.8	53.7	47.9
Transplants	48.0	47.8	52.0

LSD .05: Between seeding methods for same date and between planting dates for same method; 5.2



Average fruit weight from the transplanted crop were less than from the direct seeded crops for the May planting dates. Weight of fruits from the transplants were the same for all planting dates.

Total fruit set per plant was higher in the transplanted crop regardless of tillage system (Table 10). There were no differences, however, between the different direct seeding methods regardless of tillage system. Residues of rye and wheat reduced the number of fruits per plant in the transplanted crop as compared to the CT. Total number and weights of rotted fruits were similiar for all tillage systems (Table 11), however, early and midseason transplants had higher weights of rotted fruits than plants grown from raw or pregerminated seeds (Figure 4). There was no difference between the CT and NT treatments for the late planted tomatoes.

Differences between seeding methods and tillage systems on fruit accumulation were significant throughout the harvest period (Figure 5). Weight of fruits harvested in CT plots were always greater than those harvested in the NT plots. Fruit weights were not significantly different in the rye NT treatment when grown from either raw or pregerminated seed. Use of pregerminated seed in the CT and wheat NT plots, however, gave significantly greater yields than raw seed. Harvest of fruits from transplanted tomatoes started four weeks prior to either direct seeding method and was completed by October 17. The use of pregerminated seeds delayed the maturity but did not affect the final yields when compared to the transplanted crop grown in wheat mulch or CT systems (Figure 5). Direct seeding raw seeds reduced fruit yields regardless of the tillage system.



Table 10. Effect of tillage system and seeding method on average number of fruits/plant.

Tillage System	Seeding Method		
	Raw Seed	Pregerminated Seed	Transplants
	<u>Ripe Fruit/Plant (No.)</u>		
Conventional Tillage	25.9	23.2	68.4
Rye Mulch (NT)	14.9	25.2	46.5
Wheat Mulch (NT)	20.7	26.0	44.1

LSD .05: Between tillage system and seeding method; 13.6

Table 11. Effect of tillage system on the number and weight of rotted fruits.

Tillage System	Fruit Number	Fruit Weight (g)
Conventional Tillage	32.1 ^x	2444
Rye Mulch (NT)	27.4	1693
Wheat Mulch (NT)	24.8	1950
LSD .05	NS	NS

^xTillage system x seeding date or seeding method not significant.

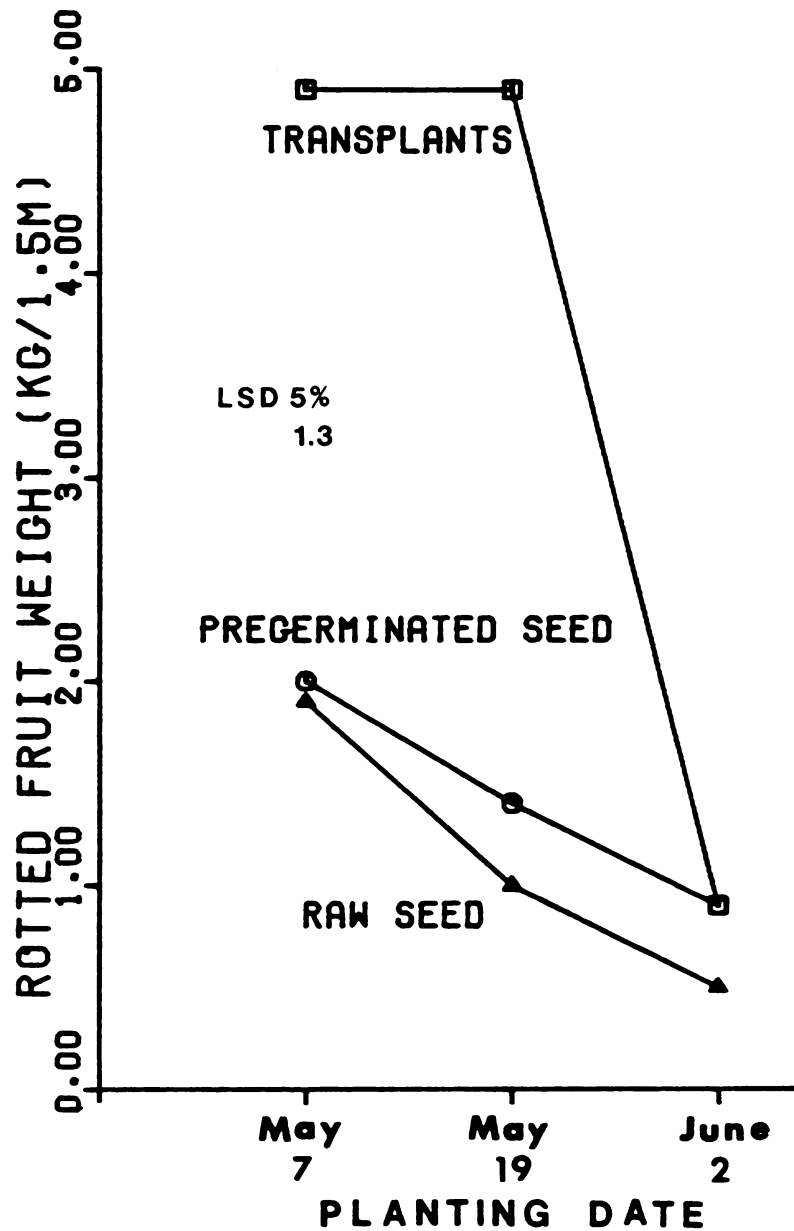
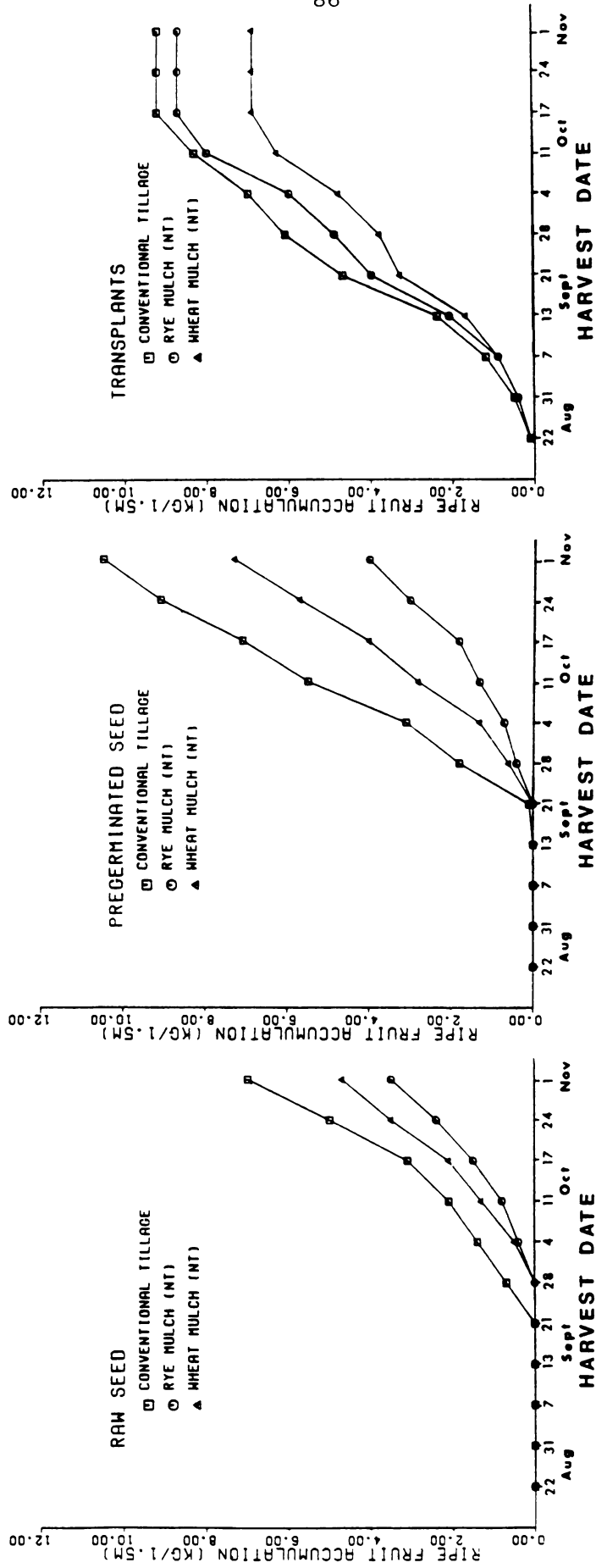


Figure 4. Effect of seeding method and planting date on the total weight of rotted fruits harvested from 1.5 meters of row. Values are the average of three tillage systems. Only fruits that were visibly diseased or cracked were harvested.



Figure 5. The effect of three tillage systems: Conventional Tillage, Rye Mulch (NT) and Wheat Mulch (NT); on the accumulation of ripe fruits when grown from raw seed, pregerminated seed or transplants. Values are the means of three planting dates.



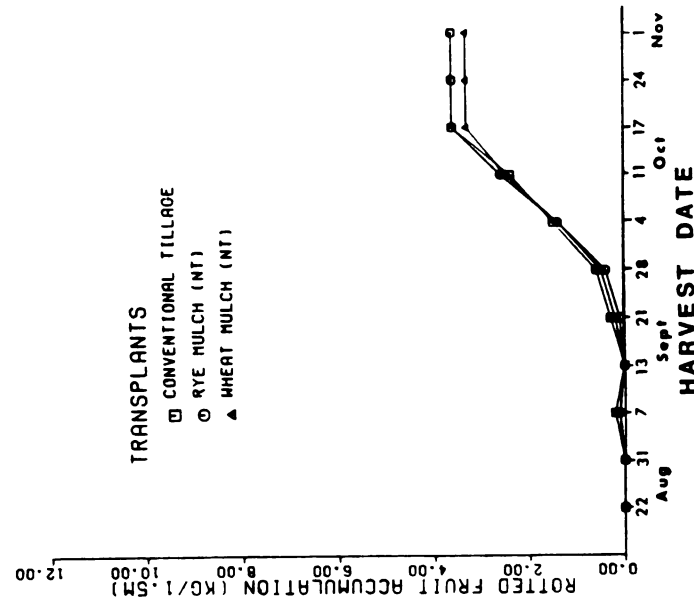
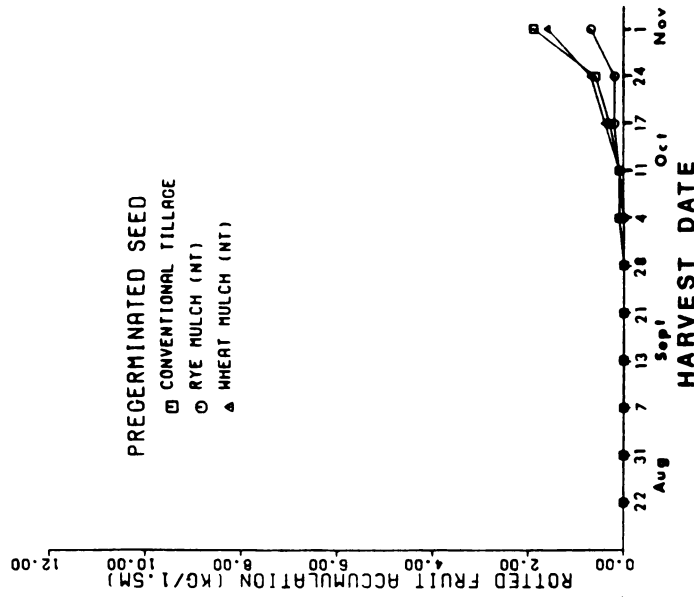
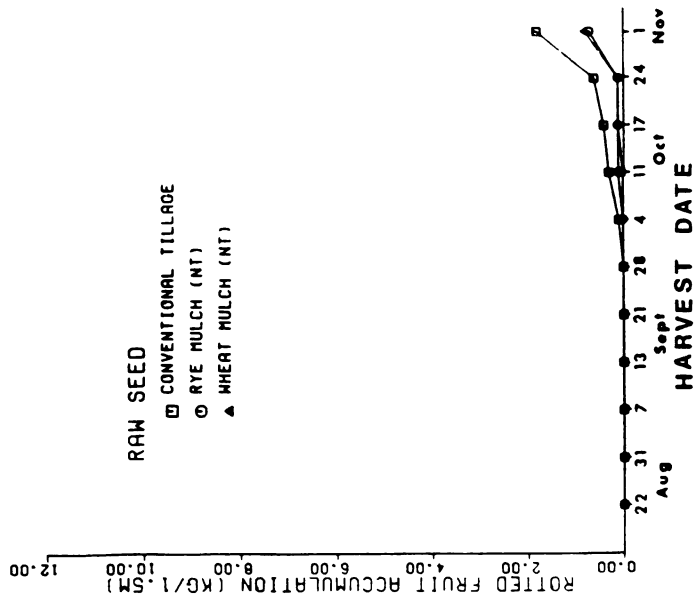
Development of rotted fruits in either the NT or CT plots followed similar trends to that of ripe fruits (Figure 6). Weight of rotted fruits was greatest for plants grown from transplants and when grown in CT plots. Harvest of rots did not start until two weeks after the beginning of the harvest of ripe fruits. Increases in the number of fruits harvested for the transplants did not begin until the first week of October. The development of rotted fruits was delayed by direct seeding (Figure 6). There were slow increases in the harvest of fruits until near the end of the growing season, at which time all tillage systems increased rapidly. Use of raw or pregerminated seeds grown in rye mulch reduced the number of rotten fruits harvested more than those grown in CT plots.

DISCUSSION

Differences between CT and NT planting with regard to flowering, plant height and dry weight may be related to cooler soil temperatures and slower plant development in NT plots. Growth of transplanted crops were not adversely affected by tillage system, however, plants grown from raw or pregerminated seeds grew slower, especially in the NT treatments. Moody (68) and Van Wijk (103) noted lower soil temperatures in NT plots reduced the early growth of corn. Bussel and Gray reported greater growth of tomato grown from pregerminated seed, with earlier flowering and higher yields than plants grown from raw seed (15), which is also demonstrated in this study. Slower development in NT treatments reduced the beneficial effect of pregermination. Residue of rye and wheat suppress plant height and dry matter accumulation of early planted direct seeded tomatoes. Phytotoxic substances produced



Figure 6. The effect of three tillage systems; Conventional Tillage, Rye Mulch (NT) and Wheat Mulch (NT); on the accumulation of rotted fruits when grown from raw seed, pregerminated seed or transplants. Values are the means of three planting dates.





from crop residues that inhibit plant growth, have been reported for many crop species (51, 76, 80). Differences noted for direct drilled tomatoes could be attributed to allelopathic leachates from decomposing rye and wheat residues, however, the influences on transplants were not as visible. Differences in plant age between the seeding methods may also allow the transplants to compete more effectively as well as tolerate the exudates from the mulches. Late plantings of direct drilled tomatoes were not influenced by the different tillage systems. Patrick reported that the toxicity of rye residue declined as the decomposition period increased (76). After 30 days, little or no phytotoxicity was observed. It may be possible that if allelopathic compounds influenced plant growth early in the season their levels were no longer sufficient to reduce plant growth in late plantings.

Soil temperatures, expressed as accumulated heat units, increased both plant height and dry weight of fluid sown tomatoes. There were no differences in plant height for any of the tillage treatments as heat units increased. Dry weight increase of tomato plants grown in the rye cover crop was slower than the wheat mulch or the conventional tillage. Factors other than temperature appear to influence the growth of tomato in rye residues. During the growing season, there were no differences in soil temperature for any of the tillage systems (Chapter 2). Soil moisture levels were lower throughout the growing season in the rye mulch plots and may have contributed to decreased plant growth (Chapter 2).

Differences in number and weight of ripe fruits were influenced by the various tillage systems. NT treatments reduced yields by 44 and 27%, respectively, for the rye and wheat mulch. Poor stands for early



plantings (Chapter 2) and problems with adequate weed control may have been responsible for part of this decrease. Slower plant growth in the NT plots may have delayed fruit maturity, thus affecting total yield. Lower numbers of flowers in both NT treatments along with fewer flower clusters, limits the number of potential sites for fruit development. Seasonal moisture levels in the rye mulch plots were significantly lower than either the CT or wheat mulch. This difference may have stressed the crop sufficiently to lower the yield. Doss (30) reported yields of transplanted fresh market tomatoes grown in no-rye plots averaged 2.2 MT/ha higher than those grown in rye plots. Reduced yields in rye plots could have been eliminated by killing the vegetation earlier in the spring. This would allow the soil profile to be recharged by rainfall without the off setting influences of the evapotranspiration by a vigorously growing rye crop.

Planting date and seeding method influences on yield of tomato have been reported by Gray et al. (47). Results obtained from this experiment were similar in nature. Early transplanting gave higher total yield than did fluid sown raw or pregerminated seeds. Early sowing of pregerminated or raw seeds gave yields of fruits similar to those from the latest transplanting (Figure 3). Early differences between the seeding methods may then in be influenced more by plant age than by method of establishment, resulting in longer picking periods and earlier harvesting of the transplants.

Differences between the tillage system and seeding date on total yield illustrates the potential limitations of NT tomato production (Table 8). Early planting dates reduced yields by 50 and 33% for the rye and wheat NT, respectively, as compared to the CT. These findings



were similar to those reported by Grenoble (49). Lack of adequate stands, potential phytotoxic compounds from decaying cover crops, slower plant growth due to cooler soil temperatures and lower moisture levels may all influence this yield reduction. Wheat mulch did not significantly alter yields for any planting dates, however, rye mulch decreased yields in both early and midseason plantings.

The average weight of fruits was greater in the direct seeded crop when compared to the transplants. At the same time, number of fruits per plant was higher for the transplanted crop. With an increased fruit load, decreased weight per fruit could be expected. The number of fruits per plant decreased when transplants were grown in residues of rye or wheat, however, the effect on total yield was not significant. Differences in average fruit weight or number per plant had no real bearing on yield differences in seeding methods or tillage system. What should be emphasized is that reduced stands in the direct seeded crops grown in NT treatments contributed to the lower yields recorded.

Tomatoes transplanted in early May had higher numbers and weights of rotted fruits than those planted late in the season. The longer growing seasons allowed many fruits to be over-ripe when picked. This prolonged ripening period along with cool, wet conditions in October favored disease development, increasing the incidence of rot. This effect was not as dramatic for either direct seeded crop. The delay of fruit set and ripening was enough to limit the number of diseased fruits harvested.

Fruit accumulation curves show the development of ripe fruits for all seeding methods and tillage systems. Weights of ripe fruits harvested in CT plots were always greater than NT plots regardless of

seeding method. Factors associated with NT appear to limit fruit development in these systems. These factors might be due to increased weed pressure in NT plots, lower soil moisture levels or slower plant growth and development throughout the season.

Fruit maturity of the direct seeded crops was about four weeks later than the transplants. It appears that plant age was responsible for early harvest differences. The benefits of early transplanting for obtaining early harvest of processing tomatoes is evident. Use of pregerminated seed has been reported to increase yields and maturity dates more than raw seed (47). Evidence here supports those findings. Yields were lower in NT plantings and appeared to be delayed more than CT plantings. Use of rye mulch decreased yields more than wheat mulch. Plant populations were lower in the rye mulch than in the wheat mulch (Chapter 2), which could have influenced final yields. Although ripening was delayed for the fluid sown pregerminated seeds, final yields of both CT and wheat NT were greater or equal to transplants grown in either of these tillage systems.

Accumulation curves for rotted fruits followed trends similar to those just discussed. Harvest began earlier in those plots established from transplants. Early planting generally had more rotted fruits harvested than late plantings. Longer ripening periods were primarily responsible for these differences. Direct seeded tomatoes were not different from each other for any tillage system.

CONCLUSIONS

Plant growth as measured by flowering, height and dry weight varied greatly between tillage systems, seeding methods and planting

dates. Growth of transplants was influenced most by planting date with late plantings developing flowers and flower clusters later in the year. Late planted direct seeded tomatoes generally were shorter and weighted less than early planted, however, by the final samplings there were no differences. Flowering patterns for the direct seeded crop were such that early plantings had more flowers and flower clusters than late plantings, with those in the CT plots having the highest number. Use of pregerminated seed increased the number of flowers for both May 7 and May 19. Both plant height and dry weight increased as heat units increased, regardless of tillage system.

Marketable yield as expressed by either number or weight decreased with NT. Yields from CT plots planted on May 7 or May 19 were significantly higher than yields from either NT treatment. Direct seeding either raw or pregerminated seed in rye residues decreased the yield of processing tomatoes, but did not affect the yields of the transplanted crop when compared to the CT plots. Yield of transplants was decreased with later planting dates, however, late planted pregerminated seed increased yield more than the early planted. Further studies need to be undertaken to understand the roles of the various tillage systems, seeding methods and planting dates on the growth and yield of processing tomatoes in the midwest.



INFLUENCE OF CHEMICAL TREATMENTS AND
RYE RESIDUES ON TOMATO

Abstract

Greenhouse experiments were initiated to more clearly define the interaction of non-selective herbicides applied to rye (Secale cereale L.) residues with seeded tomatoes (Lycopersicum esculentum Mill.). Emergence of tomato seedlings was not affected by rye residues or chemical treatment, however, plant height and dry weight of tomato were reduced when grown in rye residues. Studies of plant parts revealed that roots of rye were more toxic to growth than shoots. Plant height and dry weight of tomato was suppressed more in glyphosate (N-(phosphonomethyl) glycine) treated residues than in those treated with paraquat (1-1'-dimethyl-4,4'-bipyridinium ion). Plants grown in glyphosate treated controls and rye residues had noticeable herbicide injury symptoms. The presence of rye residues accounted for most of the decrease in the growth of tomato, however, addition of glyphosate did increase the severity of the reduction.



CHAPTER 4
INFLUENCE OF CHEMICAL TREATMENTS AND
RYE RESIDUES ON TOMATO

Introduction

The existence of allelopathy has been well documented, particularly in relation to its significance in both natural and agroecosystems (81). Several major difficulties have plagued research in this area. Among these are a lack of agreement in nomenclature, reliability in technique to separate allelopathic influences from other aspects of plant interference and a failure to prove the existence of direct versus indirect influences via intermediate organisms.

There are many factors which influence substances leached from plant residues, factors directly associated with the plant as well as those influenced by the environment (100). Phytotoxic substances from crop residues have been shown to be related to low crop productivity (29). In addition, there have been various reports of phytotoxicity in decomposing rye residues (5, 18, 76, 77). Growth inhibition from these substances is greatly dependent upon the degree of decomposition in the soil and the quantity on the soil surface (52). Shoots and roots vary in the amounts of phytotoxic compounds produced (82, 100).

Difficulty in stand establishment with direct seeding in conventionally tilled systems has created interest in applying no-tillage (NT)



practices to vegetable production systems (7, 49). Use of fluid sown pregerminated seeds has been shown to give higher and quicker emergence than raw sown seed when planted under sub-optimal conditions (47). There is little information available on the effects of reduced tillage soil management systems on the stand establishment and growth of fluid drilled crops.

Commercial herbicides may also represent stresses that influence plants (82). It is important to understand their effects on plant inhibition and crop growth. Campbell (17) reported that residual glyphosate (N-(phosphonomethyl) glycine) had no effect on germination but had deleterious effects on the establishment of surface-sown pasture species. Egley (34) noted that paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) did not affect broadleaf weed emergence but some rates inhibited grass weed emergence when the seeds were treated while on the surface. Barnes (5) reported that chemically desiccated rye residues reduced the germination of lettuce (Lactuca sativa L.) and barnyardgrass (Echinochloa crusgalli L.) and reduced the growth of tomato (Lycopersicum esculentum Mill.). Addition of glyphosate to rye residues reduced the germination and growth of lettuce and tomato more than paraquat treated residues.

Greenhouse studies were initiated to evaluate the interaction of herbicide treated rye residues with the emergence and growth of raw and germinated tomato seeds. By partitioning the residues into roots or shoots, studies on the effects of each plant part could be made and be compared to the effects of whole plants. Furthermore, differences between herbicide treated and non-treated rye residues on the emergence and growth of tomato could be investigated.



MATERIALS & METHODS

Evaluation of Residue Toxicity on Raw and Germinated Tomato Seed

In a greenhouse study of surface mulches, 24 seeds of rye (cv. Wheeler) were planted in a greenhouse soil mix (10% peat, 40% sand and 50% loam) in 25 x 25 x 7.5 cm plastic flats. The rye was grown for 30 days prior to treatment. Flats were watered daily and fertilized weekly with soluble liquid fertilizer (Millers 20-20-20, 6.0 g/l). Controls were unplanted flats that were watered and fertilized as the rye. Chemical treatments included glyphosate (1.1 kg/ha), paraquat (1.1 kg/ha) and rye control, dessicated by withholding water. Raw and pregerminated tomato seeds were planted 14 days after chemical treatment. Seeds were germinated for three days in petri dishes containing 15 ml of Vittera II hydro-gel (1.5% solution w/v), prior to planting. A dowel dibble was constructed to assist in planting and to maintain a uniform 1.5 cm planting depth. Raw and pregerminated seeds (radicles 1-3 mm) were hand placed in each hole and covered with 1 cc of gel. The design was a randomized complete block with four replications and the experiment was conducted twice. Emergence counts were taken daily on all seedlings with fully expanded cotyledons and continued until no seedling emerged for three consecutive days. Thirty days after planting, shoots were harvested, dried at 50-60°C and weighed. Data was analyzed using analysis of variance.

Evaluation of Glyphosate and Paraquat Toxicity in Different Soil Medium

A greenhouse soil mix (10% peat, 40% sand and 50% loam) and artificial soil medium (Sunshine Mix: Fison Corporation) were evaluated for residual toxicity to applied chemicals. Medias were treated with

paraquat (1.1 kg/ha), glyphosate (1.1 kg/ha) or water. Treatments were applied either one or five weeks prior to planting tomato seeds. Flats were watered daily and fertilized weekly following the chemical treatment. Tomato seeds (cv. Chico III) were germinated and planted as described previously. The experiment was a split plot with age of the medium as the whole plot and chemical and type of medium as the subplots; there were four replications. Daily emergence counts were taken and 20 days after seeding plants were harvested, dried and weighed. Data were analyzed using analysis of variance.

Root and Shoot Partitioning of Glyphosate Treated Rye Mulch

Rye was grown in artificial medium (Sunshine Mix) for 30 days before treating with 1.1 kg/ha of glyphosate. Controls were, rye killed by freezing (24 hrs. at -20°C); bare soil, glyphosate treated plus poplar excelsior; bare soil, frozen plus excelsior; and fresh soil medium. Ten days after treatment all shoots were cut from the roots with scissors after which pregerminated tomato seeds were planted. Shoots were then reapplied to flats in the following combinations; (i) roots only plus excelsior, (ii) shoots only, (iii) roots and shoots, (iv) excelsior only and (v) bare soil, for both treated and frozen rye. The experimental design was a randomized complete block with four replications. The experiment was conducted twice. Emergence and dry weight were measured for each treatment combination. Data were analyzed using analysis of variance.



Root and Shoot Partitioning of Paraquat Treated Rye Mulch

After 30 days growth, paraquat (1.1 kg/ha) was applied to rye and an excelsior covered bare soil control. Rye, frozen at -20°C for 24 hours, was used as a control along with an untreated bare soil. Seven days later all shoots were clipped from the roots and pregerminated tomato seeds planted. Combinations of roots, shoots and roots and shoots were compared. The experimental design was a randomized complete block with four replications, conducted twice. Emergence, plant height and dry weight were analyzed using analysis of variance.

Evaluation of Glyphosate and Paraquat Toxicity in Killed Rye

Three top killing treatments were applied to 30 days old rye. Glyphosate (1.1 kg/ha), paraquat (1.1 kg/ha) and freezing (24 hrs. at -20°C) were used as the kill methods. Eight days later shoots were removed, pregerminated seeds planted and combinations of roots plus excelsior, shoots only or whole plants (root and shoots) were reapplied. One additional control was added; unplanted (no rye) controls of excelsior placed in the flats at time of chemical treatment. The controls were treated with glyphosate, paraquat or frozen. Planned comparisons between the controls and chemically dessicated rye residues and paraquat and glyphosate treated residues were made to determine the influence of each treatment on emergence, plant height and dry weight.

RESULTS AND DISCUSSION

Evaluation of Residue Toxicity on Raw and Germinated Tomato Seeds

Emergence of germinated seeds sown in glyphosate treated rye mulch was reduced by 17% when compared to bare soil controls (Figure 1).



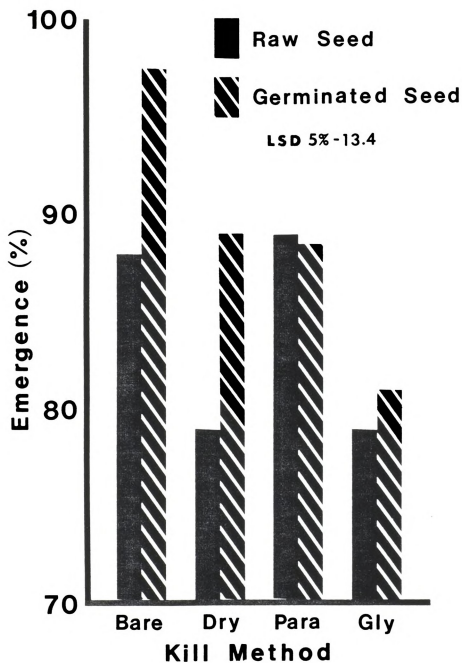


Figure 1. Percent emergence of raw and pregerminated tomato seed in rye residues killed back by several methods.



Emergence of raw seed was unaffected by the various residue treatments. There was no difference between the control and paraquat or dry killed rye residues. Barnes (5) reported a 44% decrease in the emergence of tomato grown in residues of rye (cv. MSU 13) when compared to mulches of poplar excelsior, vermiculite, peat or bare soil. Lower emergence in the glyphosate treated residues compared to bare controls may be due to the combined influences of the residue and the chemical treatment. Difficulty in assessing the role of the chemical treatments and the influences of natural products on the reduction in emergence are hard to make. If natural products are involved then both the dry mulch and the paraquat treated residues would be expected to have reduced emergence. Addition of glyphosate to rye residues may increase the amount of natural toxins produced or be actively involved in the emergence reduction.

Dry weight of tomato seedlings grown from germinated seeds were reduced in glyphosate treated rye as compared to either paraquat treated or dry residues (Figure 2). Plants were chlorotic, with leaf feathering and fiddlenecking. Rodriques (83) reported that when glyphosate was applied to wheat plants, the herbicide was exuded from the plants in concentrations high enough to injure freshly planted corn or soybeans. Thus, glyphosate may have been leached from the decomposing residues and absorbed by tomato. Residues of rye were also in contact with the growing seedlings and the herbicide may have been absorbed as the plants grew through them. Dry weight of tomato grown from raw seed was not affected by any of the treatments. This difference is not completely understood.

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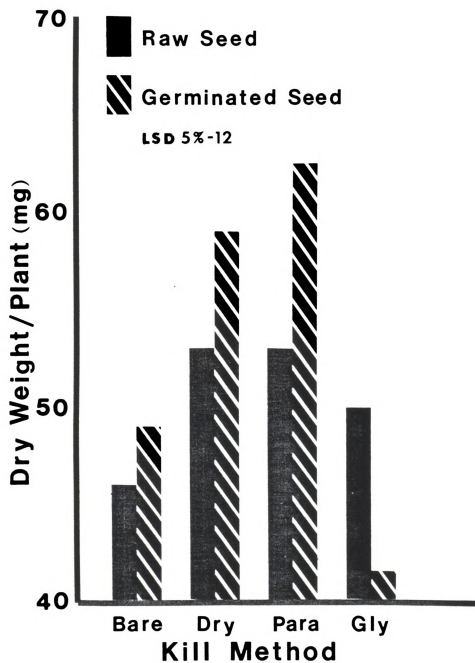


Figure 2. Dry weight of tomato plants grown from raw and pregerminated seed in rye residues killed back by several methods.

Evaluation of Glyphosate and Paraquat Toxicity in Different Soil Medium

Previous experiments suggest that contact herbicides have residual activity that influence both emergence and growth of tomato. Further studies were needed to separate the influences of the mulch residues from possible residual activity of the herbicides in the soil. These studies were conducted to look at the effect of medium age and chemical treatment on the residual activity in two different types of soil medium.

Glyphosate and paraquat usually have no apparent soil residual activity or pre-emergence effects. (2). Campbell (17) reported that residual glyphosate on the soil surface had no important effect on seed germination, but had delirious effects on plant establishment, particularly of the legumes. The residual effects were less severe at rates of 1.5 kg/ha and disappeared after 35 days.

Emergence of tomato was reduced in soil medium that was watered and fertilized for five weeks (Figure 3). Emergence was not affected by either chemical treatment or type of soil medium. Soils that were watered and fertilized for five weeks developed algae growth on the soil surface. The decreased emergence may be due to compounds exuded from the algae. In addition, fertilizer added to the medium may have increased the salt content to the point where it became toxic to emerging seedlings.

Soil medium treated with glyphosate one week prior to planting, decreased the dry weight of tomato by 50% when compared to soils treated with paraquat or water (Figure 4). In contrast, soil medium treated with glyphosate five weeks prior to seeding increased plant dry weight by 26% over water controls. Studies here suggest that applications of



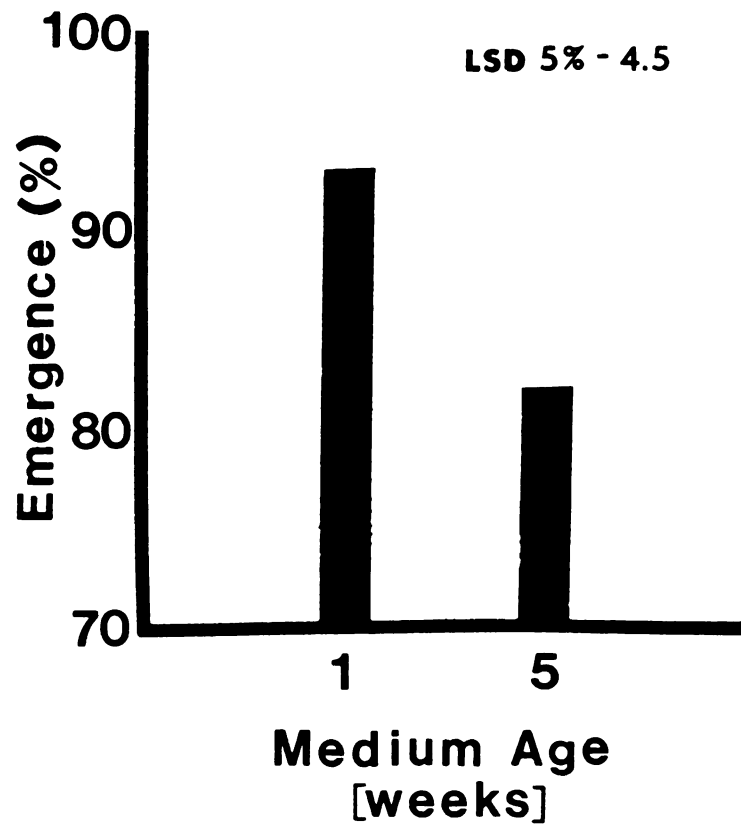


Figure 3. Percent emergence of tomato in soil medium of different ages.

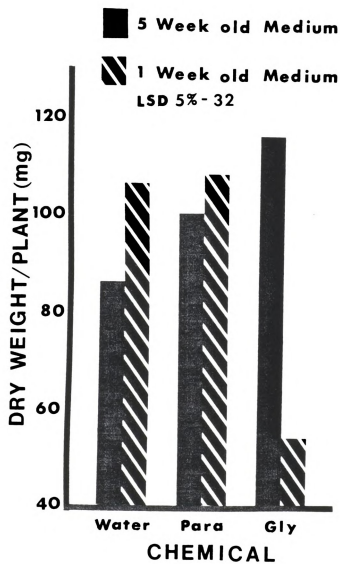


Figure 4. Dry weight of tomato in different age medium treated with several chemicals.



glyphosate shortly before seeding tomatoes should be avoided to minimize the residual effect of the herbicide. Paraquat appears to have no effect on plant growth when applied to either soil medium.

Sunshine Mix, treated with glyphosate, decreased the dry weight of tomato when compared to paraquat treated medium (Figure 5). There was no difference in the dry weight of tomato in the control and Sunshine Mix treated with paraquat. In contrast, additions of glyphosate or paraquat to greenhouse soil medium did not affect tomato dry weight when compared to the control. Taylor and Ambling (92) have reported that low rates of paraquat stimulated the growth of wheat. Differences between the glyphosate and paraquat treated Sunshine Mix may be due to residual herbicide stimulating the growth of tomato.

Root and Shoot Partitioning of Glyphosate Treated Rye Mulch

Previous research has shown that the emergence of tomato was not influenced by chemical treatment to the soil, but emergence was reduced when applied to rye residues. Additional studies were conducted to examine the influences of glyphosate and rye residues on the emergence and growth of pregerminated tomato seed. Emergence was not affected by the main effects of glyphosate, mulches or roots, however, emergence of tomato in glyphosate treated shoots (no roots) was reduced when compared to any other treatment (Table 1). Moshier (70, 71) noted that direct contact of glyphosate with some grass seeds and legumes inhibited shoot elongation but not germination. Barnes reported that germination of tomato was reduced when grown in glyphosate treated residues (5). It was hypothesized that the herbicide may have been exuded from the residue causing the germination

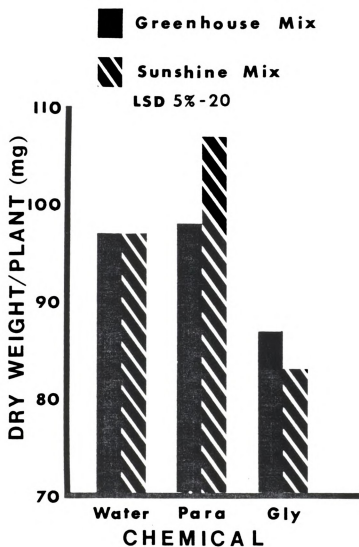


Figure 5. Dry weight of tomato grown in two soil mediums treated with different chemicals.

Table 1. The effects of glyphosate, mulches and roots on the emergence and dry weight of tomato.

Mulch	Roots	Emergence (%) ¹		Dry Wt./Plant (g) ²	
		+Gly	-Gly	+Gly	-Gly
Poplar Excelsior (PE)	-	100	100	0.66	1.71
Poplar Excelsior (PE)	+	92	95	0.63	0.75
Rye Shoots	-	72	92	1.08	1.75
Rye Shoots	+	100	93	0.47	0.87
None	-	---	98	---	1.67

¹LSD .05: For the comparisons of emergence means for the main effects and interactions of glyphosate, mulch and roots; 12.9

²LSD .05: For the comparisons of dry weight/plant means for the main effects and interactions of glyphosate, mulch and roots; .48



reduction. It was also possible that the stress of the chemical caused the rye to produce and release more natural toxins that inhibit germination and growth. A final possibility proposed was that glyphosate remained on the plant tissue where it was absorbed by the plant as it grew through the residue. Thus, if glyphosate caused any of these actions in decaying rye residues, decreased emergence should also be seen in the glyphosate treated rye shoots plus roots. Emergence was unaffected by this treatment.

Rye and poplar excelsior mulches treated with glyphosate reduced the dry weight of tomato by 44% when compared to untreated mulches (Table 1). Similarly root residues, either treated or untreated, reduced the dry weight by 48% when compared to treatments without roots. Tomato biomass was two times greater in rye shoot residues (no roots) than in rye root residues (no shoots) that had not been treated with glyphosate. These findings support previous reports of allelopathic substances being present in rye residues (5, 76), but suggest that additions of glyphosate may increase the amount of growth suppression. Tomatoes grown in glyphosate treated residues appeared chlorotic, had restricted leaf growth and compacted roots. Toai and Linscott reported that alfalfa seedling development and growth was inhibited by toxins released from dried quackgrass rhizomes and leaves treated with glyphosate (95). They recommended that delayed planting of alfalfa may allow the young seedlings to overcome the harmful effects present. Comparisons between untreated poplar excelsior and those treated with glyphosate, demonstrate some residual activity of the herbicide in the soil media (Table 1).

Root and Shoot Partitioning of Paraquat Treated Rye Mulch

Tomato seedling emergence was reduced by rye shoots (no roots) when compared to poplar excelsior plus rye roots (Table 2). There was no difference for the main effects of paraquat, roots or mulches on the emergence of pregerminated tomato seeds. Paraquat has been reported to reduce the emergence of grasses but not broadleaf weeds (4, 34). Paraquat, unlike glyphosate, is not translocated throughout the treated plant. Instead it forms a free radicle which disrupts membrane structure. Thus, it acts quickly and only when it contacts green tissue (2). Higher concentrations of paraquat in the shoots may be responsible for the reduced emergence. This however, would not explain the decreased emergence noted in the untreated rye shoots (no roots). Patrick (76) reported that residues of rye delay emergence and reduce growth of lettuce and tobacco. Exudates from decomposing rye shoots leached into the root zone may be involved in the emergence reduction.

Plant height and dry weight were reduced more by rye roots than by no roots (Table 2). Comparisons between plant parts of rye residues show that rye roots and poplar excelsior suppress growth more than rye shoots (no roots). Similarities between emergence, plant height and dry weight of the untreated and herbicide treated mulches suggest that allelopathy may contribute more to the decrease in growth than the effect of paraquat.

Evaluation of Glyphosate and Paraquat Toxicity in Killed Rye

There was no significant difference in the percent emergence of fluid sown pregerminated tomato seed grown in untreated or chemically treated rye residues (Table 3). Previous experiments support these

Table 2. The effect of paraquat, mulches and roots on the emergence, height and dry weight of tomato.

Mulch	Roots	Emergence (%) ¹		Plant Height (cm) ²		Dry Wt./Plant (g) ³	
		+Para	-Para	+Para	-Para	+Para	-Para
Poplar Excelsior (PE)	-	91	94	44.0	40.3	0.29	0.26
Poplar Excelsior (PE)	+	99	97	27.3	22.5	0.20	0.20
Rye Shoots	-	89	89	59.8	62.5	0.29	0.32
Rye Shoots	+	89	92	29.3	32.5	0.20	0.23

¹LSD .05: For comparisons of emergence % means for the main effects and interactions of paraquat, mulches and roots; 6.0

²LSD .05: For comparisons of plant height means for the main effects and interactions of paraquat, mulches and roots; 7.0

³LSD .05: For comparisons of dry weight/plant means for the main effects and interactions of paraquat, mulches and roots; .03



Table 3. The effect of glyphosate and paraquat treated rye residues on the percent emergence, plant height and dry weight of tomato.

Treatment	Plant Parts			
	Roots	Shoots	Roots + Shoots	Poplar Excelsior
	% Emergence ¹			
Frozen	78	84	91	88
Paraquat	90	89	85	91
Glyphosate	90	78	85	91
	Height (cm) ²			
Frozen	20.2	32.8	23.1	36.5
Paraquat	20.1	34.4	23.6	34.3
Glyphosate	22.8	27.4	17.8	27.2
	Dry Wt./Plant (g) ³			
Frozen	0.17	0.58	0.26	0.40
Paraquat	0.14	0.64	0.33	0.45
Glyphosate	0.20	0.46	0.12	0.31

¹LSD .05: For the comparisons of emergence means for the main effects and interactions of treatments and plant parts; 15.0

²LSD .05: For the comparisons of plant height means for the main effects and interactions of treatments and plant parts; 4.9

³LSD .05: For the comparisons of dry weight means for the main effects and interactions of treatments and plant parts; .14

findings. Emergence of pregerminated seeds does not appear to be influenced by compounds or chemicals that are leached or exuded from rye residues.

Tomatoes grown in rye residues were significantly smaller than those grown in poplar excelsior controls (Table 3). Rye root residues decrease plant height more than shoot residues. Loehwing, in Root Interactions of Plants, reviews much of the early literature dealing with the delirious effects of adjacent or succeeding crops on those following (65). Injury in these instances was characterized by slow growth, inadequate nutrient absorption, chlorosis and slow maturation. These symptoms suggest that toxic root secretions were probably the common cause of the injury. Rice (82) reported that roots and shoots of plants vary in their phytotoxic compound production, but gave no indication as to degree of difference. Plant height decreased more in rye residues and poplar excelsior treated with glyphosate than paraquat treated (Table 3). Biomass production was unaffected by chemical treatment when compared to frozen controls, however, glyphosate treated residues decreased the dry weight more than paraquat treated residues (Table 3). The greatest degree of suppression was noted when tomatoes were grown in rye root residues.

Lack of differences between frozen rye residues and chemically treated residues for emergence, plant height and dry weight support the theory that growth reductions are due more to allelopathic influences than chemical suppression. Furthermore, leachates/exudates from root residues are more toxic to growth than compounds from shoot residues. Comparisons between glyphosate and paraquat illustrate some potential problems with herbicide use in residue studies. Addition of

glyphosate to plant residues with known allelopathic properties may enhance the activity of those compounds. It is also possible that the chemical is actively uptaken from roots or shoots by young seedlings growing in the residues. It is important to remember that though greenhouse conditions are ideal for evaluating differences between chemicals and rye residues, culture of the plants is not identical to those encountered in the field. Thus, one must be careful in drawing conclusions from the greenhouse and applying them to the field.

CONCLUSIONS

Emergence of tomato was not affected by rye residues or chemical treatment in any of the trials, however, both plant height and dry weight were suppressed when grown in rye residues. All treatments were fertilized on a regular basis, thus it was assumed that there were no nutritional differences in the rye and bare soil treatments. Use of glyphosate appears to increase the degree of growth suppression more than untreated controls. In addition, noticeable herbicide injury symptoms were observed in bare soil controls and rye residues treated with the herbicide. Use of contact herbicides did in some cases increase the amount of growth suppression, however, allelopathic effects could be the result of natural toxins, microbial intermediates produced during decomposition, herbicide exudates or any combination of these.

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