ZERO TILLAGE CROP PRODUCTION IN MANITOBA

By

David Ian Donaghy

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Submitted to
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ABSTRACT

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The influence of three years of zero tillage on weed populations and crop response was studied at three locations in Southern Manitoba. The crops grown were wheat (Triticum aestivum L., cv. Manitou), barley (Hordeum vulgare L., cv. Conquest and cv. Paragon), flax (Linum usitatissimum L., cv. Noralta), and rapeseed (Brassica napus L.var. annua Koch cv. Target and cv. Turret). The crops were sown using a triple disc drill system. The weed growth at the time of seeding was controlled with 1,1'-dimethyl-4,4'-bipyridinium ion (paraquat) plus 6,7-dihydrodipyrido (1,2-a:2',1'-c) pyrazinediium ion (diquat) at 0.84 + 0.28 kg/ha, with paraquat plus (2,4-dichlorophenoxy) acetic acid (2,4-D) ester at 0.84 + 1.12 kg/ha, and with paraquat plus 3,5-dibromo-4-hydroxybenzonitrile (bromoxynil) and ((4-chloro-o-tolyl) oxy) acetic acid (MCPA) at 0.28 + 0.56 kg/ha.

Annual weed populations were lower under zero tillage than under conventional tillage. The species which were reduced in number were Setaria viridis (L.) Beauv. (green foxtail), Avena fatua L. (wild oats), Polygonum scabrum Moench (green smartweed), and Polygonum convolvulus L.

(wild buckwheat). The perennial weeds, Agropyron repens (L.) Beauv. (quack grass) and Cirsium arvense (L.) Scop. (Canada thistle), presented problems under zero tillage.

Other herbicide treatments which resulted in good weed control were paraquat at 0.28 kg/ha applied in a spray volume of 69 l/ha, 2-sec-butyl-4,6-dinitrophenol (dinoseb) at 4.48 and 8.97 kg/ha, and N-(phosphonomethyl) glycine (glyphosate) at 0.56 kg/ha. Paraquat at 0.28 kg/ha was more effective when applied in 69 l/ha spray volume than when applied in 138, 183, or 243 l/ha spray volume, and was more effective when applied in the evening than when applied in the morning. Dinoseb resulted in excellent weed control at the time of spraying and gave residual control of broad-leaved weeds, green foxtail, and wild oats. Wheat (cv. Neepawa), barley (cv. Conquest), and Avena sativa L. cv. Harmon (oats) were tolerant to dinoseb at 8.97 kg/ha. Glyphosate at 0.56 kg/ha resulted in weed control equivalent to control from paraquat plus diquat at 0.84 + 0.28 kg/ha.

More crop plants emerged under zero tillage, and these plants grew more rapidly to produce a more vigorous crop stand than the stand produced under conventional tillage. At four and six weeks after emergence, the dry weight of wheat grown under zero tillage was 200% of the dry weight of wheat grown under cultivation, while the dry weight of barley under zero tillage was 277% and 208% of dry weight of barley under cultivation, at 4 and 6 weeks respectively.

The differences in vegetative growth between treatments decreased as the crops matured.

Root development was not restricted under zero tillage, relative to conventional tillage. The only differences observed indicated that root development was superior on the zero tillage treatment.

Grain yields of wheat and barley did not differ between treatments except for barley at one location where a nitrogen deficiency was evident. Seed yields of flax and rapeseed were higher under zero tillage than under conventional tillage in four of 15 instances. Yield component evaluations indicated that both seed size and the number of seeds produced (number of fertile tillers and kernels/head for cereal crops) could be altered by the tillage treatment. Zero tillage did not have a consistent influence on any one of the yield components under the conditions of this experiment.

Nitrogen fertility trials indicated that less soil nitrogen was available under zero tillage, but additional nitrogen fertilizer was used more efficiently than under conventional tillage. At high rates of nitrogen fertilizer (101 to 269 kg/ha) crops grown under zero tillage outyielded crops grown under conventional tillage.

The study indicated that wheat, barley, flax, and rapeseed could be grown under zero tillage on three soil types (very fine sandy loam, clay loam, and Red River clay) in Manitoba, with a potential for yields greater than those produced with conventional tillage.

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INTRODUCTION

Man instigated the surging trend towards increased soil manipulation when he first tilled the soil to produce his crops. Satisfactory crops could not be produced without tillage. Weed control and seed placement required at least one tillage operation. The short term effect of tillage appeared to be positive, and the art of tillage became established as a necessity in crop production.

In the last two decades agronomists have questioned the need for tillage. The negative effects of tillage have accumulated (compaction, organic matter breakdown, and erosion). Technology has evolved until weed control and seed placement can be accomplished without tillage. Consequently, a minimum tillage trend has developed. Plow-plant, wheel-track planting, row-zone, minimum, and zero tillage techniques have been introduced. These practices originated with corn production; some have spread to other crops.

Zero tillage corn production has been accepted in some areas of the United States, occasionally outyielding conventional tillage production. Successful corn production suggests possibilities for other crops.

Advantages of zero tillage are:

i/ reduced labor and equipment requirements

ii/ reduced soil erosion

iii/ conservation of soil moisture

iv/ reduced weed populations

v/ reduced soil compaction

vi/ potentially higher yields

Trials were initiated in Manitoba to evaluate the production of four crops under zero tillage conditions. The objectives of these studies were to determine if zero tillage production of four commercial crops in Manitoba was technically feasible, to point out potential problems, and to suggest possible zero tillage management programs.

LITERATURE REVIEW

A. Tillage

Tillage has been considered a necessary operation in most crop production systems. As more advanced machinery was developed, tillage was intensified and diversified. Considerable amounts of time and capital are involved with tillage operations each year.

a) purpose of tillage

Individuals differ in their opinion regarding the purpose of tillage. Larson (1962) stated that the main purposes of tillage were to prepare the seedbed for fast and accurate mechanical planting at the proper depth, to prepare soil conditions conducive to germination and emergence of the crop, to prepare the soil for rapid infiltration, and to reduce compaction. Donahue (1961) listed the purposes of tillage as improvement of the physical condition of the soil, and control of weeds, diseases and insects. Kuipers (1970) reported the two purposes of tillage as being weed control and improvement of soil structure. English workers supported weed control as the main purpose of tillage while German workers contended that improvement of soil structure was the primary benefit from tillage (Kuipers 1970). Gill and Trouse (1972) claimed that tillage should prepare a seedbed and a rootbed for the crop.

b) tillage systems

Tillage practices can be grouped into three systems:

i/ conventional tillage - A system characterized by several tillage operations, generally three or more, depending on the type of crop. It is a system in which the number of operations is not reduced from that which farmers have normally practiced in the past.

ii/ minimum tillage - A system in which the number of tillage operations is reduced from that of conventional tillage. Generally the system involves only one or two tillage operations per year. Specialized techniques in this system include plow-plant, wheel-track planting, row-zone and stubble mulch tillage.

iii/ zero tillage (no-tillage or direct-drilled) - A system in which a crop is seeded into a non-disturbed seedbed with a minimum of soil disturbance, and chemical weed control, if necessary.

c) basis for tillage

Tillage, although being an ancient practice, has a weak basis, compared to other agrotechnical operations (Daraselia 1968). Early anti-plough movements which coincided with World War I (1914-1918) and World War II (1939-1945) resulted from a labour shortage, not scientific findings (Kuipers 1970).

d) the beginning of reduced tillage

Russell (1945, cited by Jeater 1966) was the first worker to report a direct drilling success when he demonstrated that crops could be grown from seed in undisturbed soil providing weeds were controlled. Cook et al. (1953) showed that tillage could be reduced since it was unnecessary to work the soil more than necessary to allow accurate and uniform planting. They pointed out that early results regarding the effect of tillage were obtained from soils high in organic matter and from light, horse drawn implements. Van Ouwerkerk (1969) found greater compaction on farms using tractor drawn implements than on farms where horse drawn implements were used.

e) zero tillage *Zea mays* L.

Reports of successes with zero tillage are numerous. Increased yields with no-tillage *Zea mays* L. have been found by many workers (Moschler et al. 1972, Blevins et al. 1971, 1972, Shear and Moschler 1969, Jones et al. 1968, 1969, Triplett 1966, Moody et al. 1961). Fink et al. (1970) reported equivalent *Zea mays* L. yields under no-tillage. Free et al. (1963) found decreased yields with no tillage.

f) zero tillage cereal crops

Van Keuren and Triplett (1972) and Wicks (1972) reported increased yields of winter wheat under zero tillage conditions. Jeater and McIlvenny (1965) found zero tillage winter wheat yields to be inconsistent between trials. Jeater (1966) reported that the five year average yield for zero tillage winter wheat was higher than for tilled wheat.

Hood et al. (1964) found no yield differences between no-tillage and ploughed winter wheat. Heinonen (1968) indicated that lower yields of winter wheat were produced in the absence of tillage, and Wellings (1968) reported lower yields of spring wheat and barley under direct-drilling.

Jeater and McIlvenny (1965) found no consistent differences in the yield of spring sown barley. Jeater (1966) found direct-drilled spring barley yields to be comparable to tilled barley yields when nitrogen fertility was adequate. Glabiszewski (1968) reported no yield reduction with direct-drilled oats and spring and winter wheat.

g) other zero tillage crops

Winter rape, a tap rooted crop, responded poorly to direct drilling (Bakermans and de Wit 1970, Heinonen 1968, Young 1964). Another tap rooted crop, yellow lupin, yielded poorly under no-tillage (Glabiszewski 1968).

Kincade (1972) reported that soybeans under no-tillage and tillage produced equivalent yields. Several fruit and vegetable crops could be produced without tillage (Robinson 1964). Barrons and Fitzgerald (1952) found that corn, soybeans, flax, and wheat could be grown without tillage after ladino clover. Successful pasture renovation without tillage has been reported (Woods 1972, Van Keuren and Triplett 1972, McClellan and Baylor 1972, Evans et al. 1964, Kay 1964, Ross and Cocks 1964, Sprague 1952).

h) double cropping

Lewis (1972) stated that the standout feature of no-tillage was the potential for double cropping. Examples of double cropping are cited in Table 2.1. Lewis (1972) pointed out that the southeastern United States was the area most suited to double cropping.

Table 2.1 Double cropping systems under zero tillage in the United States.

Winter Crop	Summer Crop	State
oat-ryegrass-crimson clover mixture (graxing)	corn (silage)	North Carolina
wheat	soybeans	North Carolina, Ohio
wheat	grain sorghum	North Carolina
wheat-vetch mixture (silage)	forage sorghum	North Carolina
wheat or barley	sorghum or soybeans	North Carolina
wheat	corn	Illinois, Ohio

i) <u>commercial acceptance in the United States</u>

Zero tillage has achieved commercial acceptance in some areas of the United States, especially for corn and soybean production. No-tillage is practiced on a third of a million acres, mostly in Kentucky.[1]

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1. Britannica Library Research Service - The No-Till Method of Crop Production. 1972.

B. Zero tillage research

a) seeding equipment for small seeded crops

Zero tillage requires specialized seeding equipment for proper seed placement. Several researchers reported problems with no-tillage seeding (Bakermans and de Wit 1970, Baeumer 1970, Wellings 1968, Heinonen 1968, and Jeater and M^c^Ilvenny 1965). Hood *et al*. (1964) found no winter wheat yield differences between direct drilling and plowing when the dished disc type coulter was used for seeding direct drilled plots. Wellings (1968) stated that the triple disc drill was the most suitable type of system for direct drilling. Barrett *et al*. (1972) found that the Australian "combine drill" performed adequately for direct drilling of cereal crops. Woods (1972) reported that the triple disc system was satisfactory for pasture renovation, resulting in a minimum of soil disturbance, and that two drills commercially available in Canada produced comparable results.

b) weed control

Pre-seeding weed control has been a problem with zero tillage. Russell (1945, cited by Jeater 1966) claimed that seedling crops were sensitive to weed competition but tolerant of a wide range of soil tilth conditions. Hood *et al*. (1964) emphasized the importance of the spray treatment in direct drilling, stating that direct drilling without weed control before crop emergence was not satisfactory. Heinonen (1968) reported difficulties arising from seeding before weed emergence since emphasis on selective weed control in the crop increased.

Perennial weeds presented problems for zero tillage (Kincade 1972, Peters 1972, Williams and Ross 1970, Fink et al. 1970, Brown 1968, Triplett 1966, and Robinson 1964). Robinson (1964) and Brown (1968) recommended avoidance of areas with perennial weed problems.

Atrazine at 1 - 2 lb/A controlled annual broad-leaved weeds but annual grasses such as crabgrass (Digitaria sanguinalis L. Scop and Digitaria ischaemum (Schreb.) Muhl.) and fall panicum (Panicum dichotomiflorum Michx.) were difficult to control in no-tillage corn (Peters 1972).

Schwerdtle (1970) found that annual broad-leaved weeds decreased under direct seeding. Annual grasses were variable in their response to tillage. He found one instance where Avena fatua L. were reduced under direct seeding. Schwerdtle's data indicated consistently that perennial weeds, both grasses and broad-leaved weeds, increased under direct seeding. Data from Schwerdtle (1970) is summarized in Appendix F-1.

Schwerdtle (1970) found that Agropyron repens L. increased greatly over a three year period of direct seeding. He found that Agropyron repens L. rhizomes were closer to the soil surface in the absence of tillage. Sample data is presented in Appendix F-2. In corn, Schwerdtle (1970) found that 80 kg/ha sodium salt of TCA applied in the fall and 3 kg/ha atrazine applied before planting gave 90% control of *Agropyron repens* L. This control was equivalent to control by plowing.

Toxins produced by *Agropyron repens* L. were shown to inhibit the growth of peas and wheat (Le Tourneau and Heggeness 1957). Ohman and Kommedahl (1960) found that the growth of *Medicago sativa* L. was reduced by quack grass toxins. Kommedahl *et al*. (1959) stated that alfalfa, flax, wheat, oats, and barley growth was inhibited by the quack grass decomposition products. Ohman and Kommedahl (1960) claimed that the quack grass toxins could remain in the soil for at least one year.

Peters (1972) claimed that under no-tillage, seed accumulated on the soil surface and resulted in more seeds being available for germination, surface trash reduced herbicide contact with the soil and weeds, and high organic matter at the soil surface reduced the activity of soil applied herbicides.

Robinson (1964) pointed out that in the absence of tillage weed seeds would not be brought up to the germination zone and induced dormancy would result because of soil compaction. Roberts and Dawkins (1967) found that the proportion of viable seeds giving rise to seedlings decreased from year to year on untilled plots, but the number of viable seeds decreased faster when the soil was disturbed.

Chancellor (1964) listed three response categories of weeds, according to the influence of cultivation on germination. These were:

i/ arable response weeds - germination increased when cultivation increased. eg. Raphanus raphanistrum L., Viola arvensis Murr., and Cerastium vulgatum L.

ii/ inverse response weeds - germination decreased when cultivation increased. eg. Taraxacum officinale Weber, Gnaphalium uliginosum L., Juncus bufonius L., and Sonchus asper (L.) Hill.

iii/ intermediate response weeds - maximum germination with a few cultivations. eg. Trifolium repens L., Polygonum persicaria L., Poa annua L., and Senecio vulgaris L.

The inverse response group would be favored under zero tillage. Triplett and Lytle (1972) observed shifts in annual weed populations under no-tillage.

Cussans (1966) stated that weeds with pronounced dormancy, such as wild oats, are not favored by no-tillage since the seeds are left unprotected on the soil surface. The role of birds and small mammals in the removal of wild oats from the soil surface is not small (Whybrew 1964).

The bipyridyl herbicides, paraquat and diquat, have been used for weed control in seedbed preparation in many countries of the world (Barrett et al. 1972). Since introduction a decade ago, paraquat has been tested extensively, alone and in combination, for no-tillage weed control.

Triplett (1966) claimed that paraquat alone was not satisfactory for no-tillage Zea mays L. since some residual control was necessary to prevent regrowth of weeds. He proposed that the herbicide system be formulated to control the vegetation present. In no-tillage cereal production, residual herbicides have presented tolerance problems (Phillips 1972, Whybrew 1968).

Paraquat has been tested at various application rates. Jeater and McIlvenny (1965) reported that 2 lb/A was significantly more effective than 1 lb/A of paraquat. Jeater and Laurie (1966) reported only slight differences between the 1 and 2 lb/A rates. Reduced rates of paraquat have been proven effective. Kincade (1972) reported 100% weed control at 4 oz/A of paraquat. Barrett et al. (1972) stated that satisfactory weed control was achieved with paraquat plus diquat at 2 plus 2 oz/A applied in 10 gpa (Imp) with 0.2% vv Agral 60.

Appleby and Brenchley (1968) reported that germination of legumes (Medicago sativa L. and Trifolium pratense L.) on the soil surface, sprayed with 1 lb/A paraquat was not affected but germination of seven forage grass species (Agrostis tenuis Sibth., Avena sativa L., Bromus inermis Leyss., Dactylis glomerata L., Festuca arundinacea Schreb., Festuca rubra L., and Phleum pratense L.) was reduced by 0.5 lb/A paraquat. A 0.25 inch layer of soil was effective in protecting the seeds from paraquat. Appleby and Brenchley proposed that the seed may absorb paraquat from the lemma and palea, and that grassy weeds may respond in the same way as forage grass species.

Baird *et al*. (1971) suggested the possible use of a new herbicide, N-(phosphonomethyl) glycine (glyphosate) for stale seedbeds and minimum tillage areas. This herbicide has wide spectrum activity, translocates readily, has a high degree of herbicidal activity, and is non-herbicidal when applied to mineral soil at normal use rates (Baird *et al*. 1971). Glyphosate (MON-0468) provided control of *Agropyron repens* L., the optimum rate being 1 lb/A plus 0.5 lb/A thirty days after the initial treatment (Sprankle *et al*. 1972).

c) *crop germination and emergence*

Germination and emergence was unsatisfactory under direct drilling in some instances, but this was attributed to poor seeding equipment (Jeater 1966). Soybeans germinated and emerged to a stand more rapidly under no-tillage than under conventional tillage (Kincade 1972).

Heinonen (1968) reported that initial development of rape was poorer on zero tillage than on conventional tillage. Soon after emergence, no-tillage *Zea mays* L. was growing faster and was darker in color than corn grown on tilled soil (Moody *et al*. 1961).

d) *root development*

Initial root development of cereal crops was, in some cases, reduced under direct drilling (Jeater 1968). Glabiszewski (1968) found no differences in root growth of oats and wheat, but yellow lupin exhibited root inhibition. Scharbau (1968) reported that roots of wheat and barley explored the soil more thoroughly, in both horizontal and vertical directions, but the tap root of rape did not develop as well, and more surface lateral roots were formed. Kupers and Ellen (1970) attributed the restricted root system of wheat to a concentration of nutrients in the surface soil and to soil compaction.

e) diseases and insects

Take all (*Ophiobolus graminis*) and eyespot (*Cercosporella herpotrichoides*) in wheat were reduced by direct drilling (Scharbau 1968, Schwerdtle 1970). Hood *et al*. (1964) reported a lesser percentage of tillers infested with take all under direct drilling. This decrease in disease infestation was possibly due to a change in the microclimate which favored antagonistic organisms (Brooks and Dawson 1968).

Musick (1970) warned that insects may present more of a problem under no-tillage because of a more ideal micro-environment, and reduced efficiency of insect control measures.

f) soil fertility

Higher rates of nitrogen fertilizer are required under zero tillage (Blevins *et al*. 1972, Phillips 1970, Bakermans and de Wit 1970, Heinonen 1968, and Jeater 1966). Greater leaching, microbial tie up, and potentially higher yields would require additional nitrogen fertilizer

(Phillips 1970). Restricted root development would increase nitrogen requirements (Jeater 1968). Heinonen (1968) suggested that the additional nitrogen fertilizer may be required to offset the poor stand development of rape. Blevins et al. (1972) claimed that the increased leaching of nitrogen under zero tillage may have been responsible for the increased nitrogen requirement, relative to conventional tillage. Additional nitrogen fertilizer would promote rapid crop growth which would have a weed-suppressing effect (Bakermans and de Wit 1970).

At low levels of nitrogen application, zero tillage yields were lower, but at higher levels, zero tillage yields were equal to or greater than conventional yields (Blevins et al. 1972, Jeater 1966). Wellings (1968) showed that the response of wheat and barley to nitrogen was similar under direct drilling and conventional tillage, while Kupers and Ellen (1970) found a decreased yield response for direct drilled wheat. Triplett and Van Doren (1969) found that no-tillage corn responded to higher levels of nitrogen fertilizer than did conventional tillage corn, and suggested that this was due to water relations.

Chemical summerfallow, with good weed control, accumulated more nitrate nitrogen than did tilled summerfallow (Molberg and Hay 1968). A combination of one early tillage operation and three herbicide treatments resulted in the greatest amount of nitrogen accumulation. The substitution of one tillage treatment for a herbicide treatment later in the year resulted in the same amount of nitrogen accumulation as was present under conventionally tilled summerfallow (four tillage operations). Arnott and Clement (1966) found no difference in the rate of mineralization of nitrogen between tilled and chemical summerfallow. They attributed the difference in total nitrogen build up to the mineralization process starting earlier when the soil was disturbed.

Paraquat has not been shown to produce significant changes in nitrification or microbial populations (Tu and Bollen 1968a, 1968b). The use of paraquat to replace tillage would not have a direct effect on nitrogen fertility.

Bakermans and de Wit (1970) and Moschler _et al._ (1969) found a higher level of organic matter in the surface layer of zero tillage soil. More nitrogen and organic matter was reported under no-tillage _Zea mays_ L. (Moschler _et al._ 1972). In contrast, Oveson and Appleby (1970) found less accumulation of nitrogen in the absence of tillage.

Tillage practices are known to reduce the soil organic matter. Brown _et al._ (1942) reported a loss of one fifth to one third of the organic matter in a period of thirty years. Poyser _et al._ (1957) found a 27.9% decrease in organic carbon over a twenty-five year period of cropping in Manitoba.

Shear and Moschler (1969) found that phosphorous was more available with no-tillage and that potassium was not affected. Under no-tillage, more frequent liming was required. Moschler et al. (1972) reported phosphorous was used more efficiently by corn because of increased soil moisture on non-disturbed soil and Singh et al. (1966) found an increase in the uptake of fertilizer phosphorous by corn in the absence of tillage.

Estes (1972) reported that Ca, Mg, Zn, Mo, B, and Al concentrations in corn leaf tissue was reduced under no-till conditions, relative to cultivation, while K concentration was increased and P, Fe, and Mn did not differ between treatments. He attributed the Ca and Mg decreases to the K: Ca: Mg interaction.

Belcher and Ragland (1972) found no differences in P content of *Zea mays* L. forage under no-till conditions when P fertilizer was broadcast, or when some P was banded and the remainder was broadcast. They stated that increased soil moisture, increased root growth in the surface soils, and decreased contact between P and soil may have increased P availability.

With zero tillage, phosphorous, potassium and organic matter tended to concentrate in the surface layer of the soil more than when soil was tilled (Bakermans and de Wit 1970). Triplett and Van Doren (1969) obtained similar results with phosphorous and potassium.

g) soil moisture

Improved soil moisture conditions under zero tillage, relative to conventional tillage, have been claimed by many workers. Lillard and Jones (1964) reported 0.3 inches more moisture available in the top 6 inches of soil, and 0.7 inches more moisture in the top 24 inches under no-tillage than under conventional tillage. Jones et al. (1968) found 0.07 to 1.2 inches more moisture in the root zone with no tillage. Moody et al. (1961) found more moisture in the upper 18 inches of soil with zero tillage. Blevins et al. (1971) found a greater ability to store moisture, reduced evaporation, and a higher water content from 0-60 cm, especially 0-8 cm, with no difference beyond 60 cm, for no-tillage corn. Moschler et al. (1969) indicated better soil moisture conditions under no-tillage. Maximum water conservation was achieved with no-tillage (Triplett et al. 1964). The additional moisture present under zero tillage permitted crops to tolerate drought conditions one to two weeks longer than tilled crops (Shanholtz and Lillard 1969).

Van Ouwerkerk and Boone (1970) suggested that capillary transport of water was better with zero tillage than with conventional tillage. Infiltration of rain water was increased by tillage (Burwell et al. 1966) and by straw mulches (Koshi and Fryrear 1971, Barnes et al. 1955, Duley 1939). Mulches served to reduce evaporation (Koshi and Fryrear 1971, Buckman and Brady 1969). Tillage which produced an uneven micro-relief increased depression storage of water (Larson 1964).

C. Effect of tillage on soil properties

a) soil compaction

Tillage, which is used to prepare both seedbed and rootbed, often prepares a good seedbed but results in a less desirable rootbed (Gill and Trouse 1972).

Tillage generally decreases the bulk density of the tillage zone, but the results vary with the equipment. Larson (1962) found that plowing reduced the bulk density of the tillage zone from 1.4 to 1.0 g/cc. Scherbakov (1970) found that plowing decreased the bulk density from the 10-20 cm depth but increased the bulk density from the 0-10 cm depth. Roto-tilling reduced bulk density from 1.17 to 1.09 g/cc. At the 20 cm depth, penetrometer resistance was higher after roto-tilling than after plowing. Burwell et al. (1966) reported that plowing decreased bulk density more than other tillage operations. Cultivation had a small effect while rotovation had an intermediate effect. Discing and harrowing increased bulk density when carried out after plowing.

Tillage operations tend to form tillage pans and traffic pans which restrict root growth. Tillage pans have been noted by many workers (Bear 1965, McCracken and Weed 1963, Hilgard 1910). Traffic pans have also been reported (Donahue 1961, Bolton and Aylesworth 1959, Baver 1956).

Donahue (1961) stated that in Connecticut, tilled surface soils were 2.5 times more dense than when the forest was first cleared. Cultivated soils varied up to 40% depending on management practices. Donahue (1965) presented data showing bulk density increases of 66 to 82 lb/ft^3 from 0-1 foot, of 70 to 87 lb/ft^3 from 1-2 feet, and 77 to 91 lb/ft^3 from 2-3 feet. This increase was attributed to compaction due to tillage and organic matter breakdown.

At seeding, bulk density was 1.54 g/cc under no-tillage and 1.37 g/cc on tilled soil (Lillard and Jones 1964). Triplett et al. (1968) found bulk density was increased in the 0.5 - 3.6 inch layer under no-tillage corn. In contrast, Shear and Moschler (1969) reported no significant differences in bulk density between conventional and no-tillage treatments.

b) soil structure

The detrimental effect of excessive and improper tillage on soil structure has been noted many times (Bear 1965, Larson 1962, Donahue 1961, Baver 1956, Swanson et al. 1955, Beacher and Strickling 1955, McGeorge and Breazeale 1938). Optimum soil moisture levels for improved structure due to tillage are critical (Swanson et al. 1955, Russell 1938), and make timing of tillage operations difficult. Plowing generally produced a better soil structure than other tillage operations (Williams 1935) with fall plowing being better than spring plowing (Flocker 1964).

c) soil temperature

Soil temperature can be influenced by tillage practices.

Temperature at the 2 inch depth was lower under no-tillage than under conventional tillage with the difference being 4 degrees Fahrenheit at the time of crop germination (Lillard and Jones 1964). Wicks (1972) reported that the stubble left on the surface by no-tillage reduced the soil temperature and consequently reduced tillering of winter wheat. The effect of straw mulch decreasing soil temperature has been recognized (Moody et al. 1963, Burrows and Larson 1962). The mulch damps the temperature variation, having its greatest effect on daily maximum temperature when plants are growing most actively (Burrows and Larson 1962).

Increasing bulk density and soil moisture increases the heat capacity of the soil, requiring more time for the soil to warm up but also increasing the time required for it to cool down (Larson 1964).

Decreasing soil temperature has a detrimental effect on germination, root growth, plant development, soil microbiological processes, and absorption and transport of water and nutrient ions (Buckman and Brady 1969).

d) erosion

Harrold et al. (1967) reported a forty-six fold reduction in soil erosion when zero tillage was compared with conventional tillage. Woodruff (1972) indicated that wind erosion is a dominant problem in 55 million acres of cropland in the United States. Specialized wind erosion control measures are needed for 66 percent of this land.

Soil erosion is a major transport method for agricultural chemicals (Edwards 1972). By reducing soil erosion to almost zero, no-tillage offers a solution to soil transport of agricultural chemicals as well as to pollution from soil particles. Dust storms result in a much higher concentration of particles in the air than is considered tolerable for quality air (Woodruff 1972). Sediment from soil erosion has been identified as the most serious pollutant in terms of volume, in the United States (Harrold 1972).

MATERIALS AND METHODS

A. Locations and details

a) locations

Field experiments were established at three locations in 1969 on land which had received no tillage since June 1968. The soil at Carman was a very fine sandy loam. Portage la Prairie (Portage) was a clay loam and Sanford was a Red River clay. Soil characteristics for Carman and Sanford are presented in Appendix A-2. Portage soil texture characteristics are omitted because the site was variable.

b) plot history

The history of the Carman and Portage sites prior to 1969 is given in Appendix A-4. The Carman site had been subjected to continuous cropping for at least six years while the Portage site had been continuously cropped for nine years. At Sanford, a cropping rotation of wheat-oats-flax-summerfallow was practiced. In 1968 wheat was produced on the site.

c) precipitation and temperature

Meteorological data is presented in Appendix A-1. This data was extracted from the Monthly Record Meteorological Observations of the Canada Department of Transport.

d) experimental design and treatments

The experimental design was a randomized complete block with three treatments and six replicates at each location. The treatments included a conventional tillage operation, and two zero tillage treatments, as follows:

i/ ZT 1 - Plots in this treatment received no tillage. Crops were drilled directly into the stubble and weed growth was controlled with 0.84 kg/ha paraquat plus 0.28 kg/ha diquat, applied in 112 to 168 l/ha. of water, prior to or immediately after seeding.

ii/ ZT 2 - This treatment was similar to ZT 1 except that in 1969 and 1970 a herbicide mixture of 0.84 kg/ha paraquat plus 1.12 kg/ha 2,4-D ester was used. In 1971 the mixture was replaced by 0.28 kg/ha paraquat plus 0.56 kg/ha bromoxynil plus MCPA.

iii/ Cult - This treatment received conventional tillage operations. Appendix B-1 lists the tillage operations.

In 1971, quackgrass presented a severe problem at Portage. Two weeks prior to seeding, both zero tillage treatments received 1.12 kg/ha paraquat applied in 558 l/ha. The cultivated treatment received an additional tillage operation.

Individual plots were 36.6 x 106.7 meters (0.39 hectare) at Carman and Sanford and 24.4 x 152.4 meters (0.37 hectare) at Portage, resulting in a total experimental area of 21 hectares. Each plot was divided lengthwise into four equal strips and the four crops (wheat, barley, flax and rapeseed) were randomly assigned. A cropping sequence of wheat-flax-barley-rapeseed was followed.

e) <u>seeding</u>

Seeding was accomplished using a modified Kirschmann double-disc press drill. The drill was equipped with semi-pneumatic packer wheels and heavy duty pressure springs. For zero tillage plots a cutting disc 26 cm in diameter was attached to improve penetration. Figure 3.1 indicates the triple disc arrangement. For flax and rapeseed, it

Figure 3.1 Triple disc drill assembly.

was possible to remove the cutting disc to reduce soil disturbance and still obtain adequate penetration, provided that the soil was moist and trash levels were relatively low. In 1969 the drill was adjusted to seed rows with 15 cm spacing. In 1970 and 1971, adjustments were made to increase row spacing to 18 cm. This was done to improve the trash clearance of the drill.

Seeding rates of 67, 74, 9, and 45 kg/ha were used for wheat, barley, rapeseed, and flax respectively in all years. High quality seed was used in all instances. Certified seed was used when available. Registered or Foundation seed was used when necessary. Varieties grown are listed in Appendix B-3. When seed was not treated at time of purchase, a drill box seed treatment was applied. Lindasan[1] and Agrox n-m[2] were used for rapeseed and flax respectively. Mergamma n-m[3] was used for wheat and barley.

f) <u>fertilizer</u>

Fertilizer was applied at rates recommended according to soil test analysis carried out by the Provincial Soil Testing Laboratory. Rates applied are given in Appendix B-4. Phosphate fertilizer was drilled with the seed. When nitrogen requirements could not be met by drilling fertilizer, additional nitrogen was broadcast, either in a granular or liquid form.

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1. Drill box seed treatment containing 10% captan and 37.5% lindane (Green Cross Products).

2. Drill box seed treatment containing maneb and hexachlorobenzene (Chipman Chemicals Ltd.).

3. Drill box seed treatment containing maneb and lindane (Chipman Chemicals Ltd.).

g) weed control

Post emergence weed control was accomplished by using recommended herbicides (MDA Guide to chemical weed control 1969, 1970, 1971). The same herbicides were used for all three treatments. Herbicides used, rates, and dates of application are presented in Appendix B-5. Malathion 50% EC at 0.45 l/ha was used for control of flea beetles in rapeseed as required.

h) trash

After data was recorded and experimental samples were taken, the plots were harvested by the farm co-operator, using commercial harvesting equipment. Wheat, barley, and rapeseed trash was chopped and left on the plots. Flax straw was removed from the plots and burned. In the spring of 1969 a very heavy stubble necessitated burning before trials were initiated at Sanford.

B. Experimental procedures for large scale trials

The experimental plots previously described were used to compare various aspects of zero and conventional tillage. Samples and counts were taken randomly from the plots, with subsampling as required.

a) weed counts

Weed population evaluations were made prior to post emergent herbicide applications. Due to time limitations in the initial year, a rating system was utilized (Table 3.1). In the second and third years actual counts of weeds present were recorded. Both ratings and counts of weeds were based on an average of 4 to 5 subsamples (0.25 m^2) from each replication.

Table 3.1 Rating scale used in first year of zero tillage trials (1969).

Rating	Plants/0.25 m^2
1	1 - 5
2	6 - 10
3	11 - 15
4	16 - 20
5	20 +

In May 1971 samples were taken to determine the weed seed population in the 0 - 8 cm layer of soil of zero tillage (ZT 1) and normal tillage treatments. Five subsamples from within each crop replication were mixed and equal portions (two subsamples) were placed in plastic dishes in the greenhouse. The air dry weights of the soil samples were 300, 300, and 320 grams for Carman, Portage, and Sanford respectively. Watering and stirring of samples were carried out as required. Seedling weeds were counted and removed as soon as they could be identified. The samples were given a six week cold treatment (4°C) thirteen months after sampling and were then returned to the greenhouse. The samples were maintained under condition conducive to germination for a total of eighteen months.

b) <u>crop emergence and vegetative development</u>

Counts of emerging crop plants were obtained by counting the number of seedling plants in three adjacent rows, each 0.5 meters in length. Four subsamples were taken from each replication. The number of seeds deposited by the drill per meter of row was determined to allow evaluation of percent emergence. Seed counts were carried out at settings for 18 cm row spacings. Values for 15 cm row spacings were calculated from 18 cm spacing values.

On June 28, 1971, all crops were sampled (one sample per replicate) to measure vegetative dry weight under ZT 1 and cultivation. The foliage of 0.5 meter of row was collected and dried for 72 hours at 80°C and weighed.

In 1972 one zero tillage and one conventional tillage plot at Carman were maintained to study changes in foliage dry weight. Plots were managed in the same manner as fertility trials (Carman A) which will be discussed later. Nitrogen fertilizer (34-0-0) was broadcast at a rate of 34 kg N/ha.

Foliage samples were taken on June 13, June 27, July 11, and July 24. Samples were taken by collecting the foliage of 30 cm of row, with three replications for each treatment. Samples were dried for 72 hours at 80°C and weighed.

c) root development

Preliminary studies were carried out in 1970 to determine differences in root development between tillage treatments. Pits were dug in the plots and the soil was washed away from the roots with a gentle flow of water. The root development was then evaluated.

In 1971, an 11.4 cm core sampler[1] was used to sample each crop in each replication (Figure 3.2). Sampling dates are presented in Table 3.2. At Carman, core samples were taken from 15-30, 30-46, 46-61, 61-76, 76-91, and 91-108 cm depths. Roots were washed out using a pressurized stream of water and a 2 mm sieve. Root samples were oven

Table 3.2 Sampling dates for determination of root development and soil moisture (1971).

	CROP			
Location	Wheat	Barley	Rape	Flax
Carman	July 8	July 8	July 9	July 14
Portage	July 21	July 21, 22	July 22	July 23
Sanford	Aug. 4	Aug. 4	Aug. 6	Aug. 6

1. Constructed by the Department of Agricultural Engineering, University of Manitoba.

Figure 3.2 Soil core sampler.

dried (80^{o}C) and weighed. At the other sites, the cores were split in half lengthwise and some soil was washed away to allow evaluation of root development. The depth to which two separate main roots could be found in the core was recorded as the depth of major root development. Maximum depth of development was taken as the lowest depth at which crop roots could be found. Photographs were also used to record observations on root development.

d) soil moisture

Soil moisture contents were taken gravimetrically, in conjunction with root sampling. Sampling depths were 15, 30, 46, 61, and 91 cm.

e) moisture stress

The relative plant moisture stress of wheat and barley was measured in 1970 and 1971 using a pressure bomb designed by Waring and Cleary (1967) (Figure 3.3). The method was developed by Scholander et al. (1965).

In 1971, relative turgidity of rapeseed and flax was determined by weighing a detached leaf, placing the leaf in water until it reached saturation (4-6 hrs), and weighing again. The ratio of moisture content in the field to saturation moisture content, multiplied by 100, yielded relative turgidity (%). The technique was similar to that described by Barrs and Weatherly (1962) except that whole leaves were used in place of leaf discs.

f) maturity

Visual examination revealed that zero tillage plots

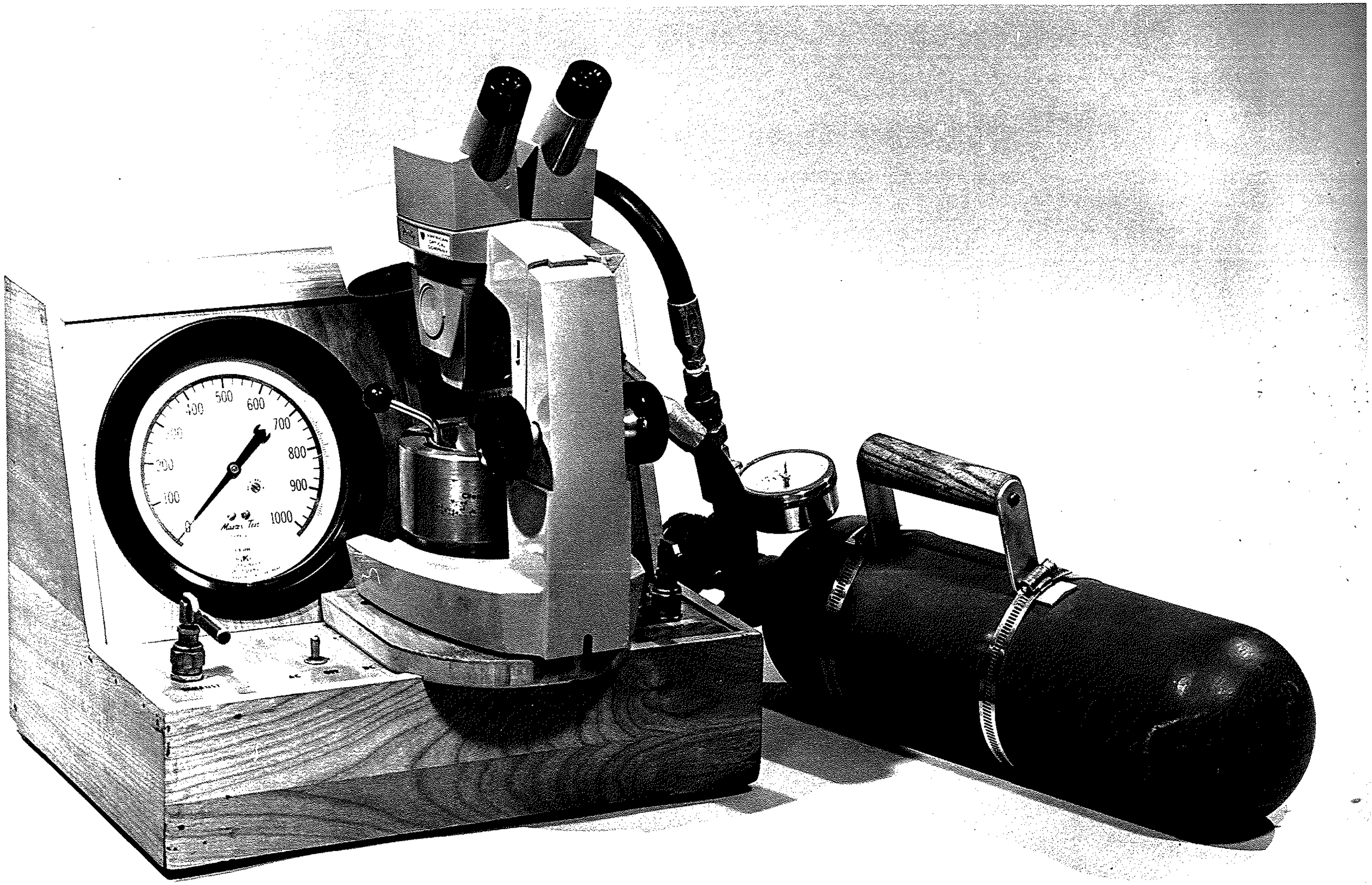

Figure 3.3 Pressure bomb apparatus.

were maturing earlier than conventional tillage plots. At Carman and Sanford, in 1971, head samples of wheat and barley from ZT 1 and cultivated treatments were taken prior to maturity to determine moisture content. At Portage, head samples of wheat were taken. Barley was not sampled but maturity differences were obtained by measuring moisture content of harvested grain samples.

g) yield and yield components

Yield data was obtained by harvesting samples from plots. Harvest techniques varied considerably. Appendix C-2 indicates sample size and method of harvesting. In 1970 and 1971, a Hege 125 plot combine was used to harvest most samples (Figure 3.4). Data was not obtained for

Figure 3.4 Hege 125 plot combine.

Carman, 1970, due to hail on July 25. Adverse weather conditions resulted in severe shattering of rapeseed at Sanford in 1971 and therefore yield results are not available. Bushel weight and kernel weight determinations were conducted on all harvest samples. In 1970 and 1971 moisture content was determined. In 1971, kernels per head data from ZT 1 and the cultivated treatment was recorded for wheat and barley.

Fertile tiller counts were obtained for wheat and barley. Fertile tillers in three adjacent 0.5 meter rows were counted. Four subsamples were taken from each replication. At Portage, in 1969, data was recorded on the basis of tillers per plant.

h) <u>protein and oil content analysis</u>

Protein content (macro-Kjeldahl nitrogen) of wheat and barley samples from 1970 and 1971 was determined. Oil content of rape and flax seed was determined for samples from 1970.

i) <u>soil fertility</u>

Soil samples were submitted to the Provincial Soil Testing Laboratory for analysis of nitrogen, phosphorous, and potassium. Samples were taken from Portage during the last week of July 1969. In 1970, samples were taken from all three locations during the last week of July. All four crops from ZT 1 and the cultivated treatment at Carman were sampled on May 10, 1972.

C. Experimental procedures for chemical seedbed trials (1972)

Trials were initiated in 1972 to evaluate herbicides for control of weeds prior to seeding.

Trials were conducted on a sandy clay loam soil at Carman. Buckwheat had been grown on the plot area in the previous year. Neepawa wheat was seeded into stubble on May 27, at 67 kg/ha, using the Kirschmann triple disc drill adjusted for 18 cm spacings. Fertilizer (11-48-0) was drilled at 53 kg/ha. Bromoxynil plus MCPA at 0.56 kg/ha, in 134 l/ha water, was applied on June 7 for selective weed control in the crop.

Individual plots were 2.7 x 7.6 meters. Each treatment had three replicates. Herbicides were applied using a 2 meter bicycle sprayer.

Weed control ratings were taken on two dates, May 31 and July 6. The rating system is outlined in Table 3.3. The weed population is described in Table 3.4. The weed canopy was 8 - 13 cm in height at the time of spraying.

Table 3.3 Weed control rating system used in 1972.

Rating	Verbal Description
1	as untreated
2	very poor
3	poor
4	unsatisfactory
5	just satisfactory
6	satisfactory
7	good control
8	very good control
9	completely destroyed

Table 3.4 Weed species and numbers present in chemical seedbed trials.

Species	Plants/square meter
wild oats	0 - 108
green foxtail	108 - 324
wild mustard	11 - 32
lamb's quarters	54 - 162
red root pigweed	0 - 32
volunteer buckwheat	0 - 32

a) <u>evaluation of several herbicides for chemical seedbed preparation</u>

Chemicals and rates used for this trial are indicated in Table 3.5. Chemicals were applied in water at 138 l/ha and 2.48 kg/cm^2 pressure on May 28, five hours after sunrise.

Table 3.5 Chemicals and rates used for chemical seedbed preparation.

Treatment	Rate (kg/ha)
check	———
paraquat + diquat	0.84 + 0.28
nitrofen	1.34
2,4-D amine	0.84
dicamba + 2,4-D + mecoprop	0.56
bromoxynil + MCPA	0.56
bromoxynil + MCPA + paraquat	0.56 + 0.28
bromoxynil + MCPA + paraquat	0.56 + 0.14
amitrol-T	4.48
dinoseb	4.48
dinoseb	8.97

b) <u>evaluation of low rates of paraquat and paraquat-diquat mixtures for chemical seedbed preparation and comparison of early morning and late evening applications of paraquat</u>

Table 3.6 indicates the herbicides rates, and times of application. All chemicals were applied in water at 243 l/ha and 2.46 kg/cm^2 pressure. Late evening applications were made on May 27. Morning applications were made on May 28, 3 hours after sunrise.

Table 3.6 Chemicals, rates and time of application for chemical seedbed preparation.

Treatment	Rate (kg/ha)	Time (AM or PM)
check	—	—
paraquat + diquat	0.84 + 0.28	AM
paraquat	2.24	AM
paraquat	1.12	AM
paraquat	0.56	AM
paraquat	0.42	AM
paraquat	0.28	AM
paraquat	0.14	AM
paraquat	0.07	AM
paraquat + diquat	0.28 + 0.28	AM
paraquat + diquat	0.28 + 0.14	AM
paraquat + diquat	0.14 + 0.14	AM
paraquat	0.28	PM
paraquat	0.14	PM
paraquat	0.07	PM

c) evaluation of effect of spray volume on efficacy of paraquat applied at low rates

Rates of paraquat and spray volumes are indicated in Table 3.7. Treatments were applied 2 to 3 hours after sunrise on May 28.

Table 3.7 Rates of paraquat and spray volume used for chemical seedbed preparation.

Treatment (kg/ha)	Spray Volume (l/ha)
check	—
paraquat 0.56	69
paraquat 0.56	138
paraquat 0.56	183
paraquat 0.56	243
paraquat 0.28	69
paraquat 0.28	138
paraquat 0.28	183
paraquat 0.28	243

d) MON 2139 (glyphosate) and low rates of paraquat

Table 3.8 indicates the treatments. A spray volume of 138 l/ha was used. Pressure was set at 2.46 kg/cm^2. Treatments were applied on May 28, four hours after sunrise. For the split application treatment, paraquat was applied on June 1, PM.

Table 3.8 Herbicides and rates applied for chemical seedbed preparation.

Treatment	Rate (kg/ha)
check	——
MON 2139	0.07
MON 2139	0.14
MON 2139	0.28
MON 2139	0.56
MON 2139	0.84
MON 2139	1.12
paraquat + diquat	0.84 + 0.28
paraquat	0.56
paraquat	0.28
paraquat	0.14
MON 2139 + paraquat (split application)	0.14 + 0.14

D. Greenhouse trials

Greenhouse trials were initiated in the fall of 1972 to obtain information to supplement results of 1972 field trials.

The effect of spray volume and the addition of a surfactant (Agral 90) was evaluated under greenhouse conditions. Pots containing weeds listed (Table 3.9) and in the stages indicated (Table 3.9) were sprayed with the treatments indicated in Table 3.10. Treatments were rated one week after application, using the same rating system as was used in the field trials.

Table 3.9 Weed species and stages at time of spraying for greenhouse paraquat trial.

Species	Stage
green foxtail	3 - 5 leaf
wheat	3 leaf
wild oats	3 leaf
green smartweed	cotyledon - 2 leaf
wild mustard	cotyledon - 2 leaf

The residual effect of dinoseb was evaluated by planting green foxtail, wild oats, wheat and barley in 15 cm diameter cans containing a soil mixture of three parts loam, one part sand and one part peat. Green foxtail (40 seeds per pot) was planted at a depth of 1.5 cm. Wheat, and barley (6 seeds per pot), and wild oats (15 seeds per pot) were planted at a depth of 3 cm. Two days after planting, dinoseb at rates of 0, 4.48, 8.96 and 17.92 kg/ha in 342 l/ha spray volume was applied. Each treatment contained 6 replicates arranged in a completely randomized design. Emerging plants were counted and dry weight of foliage was determined three weeks after treatment.

Table 3.10 Treatments applied in greenhouse paraquat trial.

Formulation	Agral 90 (%)	Spray Volume (l/ha)
check	—	—
aerial paraquat [a]	0.1	57
aerial paraquat	0.1	128
aerial paraquat	0.1	171
aerial paraquat	0.1	331
paraquat [b]	—	57
paraquat	—	128
paraquat	—	171
paraquat	—	331
paraquat	0.1	331

a Formulation of paraquat containing no wetting agent (Chipman Chemicals Ltd.).

b Formulation of paraquat containing wetting agent (Chipman Chemicals Ltd.).

A similar trial was conducted with tame oats (var. Harmon), but only the check and 8.96 kg/ha rate were used.

A trial was conducted to determine the effect of 2,4-D amine and ester on the emergence of green foxtail on the soil surface and at a depth of 1 cm. The effect of paraquat on germination of green foxtail on the surface was also evaluated.

Green foxtail seeds (20 per 10 cm diameter can) were planted in a soil mixture of three parts loam and one part sand. For surface seeds, the soil was moistened and twenty seeds were placed on the surface of the soil. Treatments indicated in Table 3.11 were applied in 171 l/ha spray volume. Each treatment contained 10 replications.

Table 3.11 Treatments applied for evaluation of 2,4-D and paraquat on emergence of green foxtail.

Planting Depth (cm)	Herbicide and Rate (kg/ha)
0	check
0	2,4-D amine 1.12
0	2,4-D ester 1.12
0	paraquat 1.12
1	check
1	2,4-D amine 1.12
1	2,4-D ester 1.12

The number of green foxtail seedlings was counted two weeks after herbicide application.

E. Experimental procedures for fertilizer response studies in 1972

Fertility problems were apparent from large scale trials. In 1972 nitrogen response trials for wheat, barley and rape were set out on plots from the three year large scale study at Carman (Carman A). Plots were 3 x 8 meters. Two tillage treatments (zero and conventional) and seven rates of nitrogen (0, 34, 67, 101, 134, 202 and 269 kg/ha) were applied with three replications. A 1.5 meter "Gandy" fertilizer spreader was calibrated for ammonium nitrate fertilizer (34-0-0) and was used to apply the different rates of nitrogen. For rates of 101 kg/ha and greater, 67 kg/ha was applied at the time of seeding and the remainder was applied two weeks later.

Additional trials with wheat and barley were laid out on a sandy clay loam soil at Carman (Carman B). The same rates of nitrogen were applied to 3 x 6 meter plots with five replicates for each treatment.

All treatments received 45 kg/ha P_2O_5 (11-48-0 drilled with seed). The amount of nitrate nitrogen present to a depth of 73 cm at the time of seeding is indicated in Appendix A-3. Weed control treatments are indicated in Appendix B-6. At maturity, yield samples were taken with a Hege 125 combine. Wheat and barley were straight combined. Rape was cut and piled to dry before threshing with the plot combine. Samples of wheat and barley were analyzed for protein content.

F. Statistical analysis

Analysis of variance was conducted using a combination of an IBM 360 computer, an Olivetti Underwood Programma 101, and an electronic desk calculator.

The randomized complete block trials with no subsampling were analyzed according to pages 134-137 of Steel and Torrie (1960). When subsampling was carried out, data was analyzed according to pages 142-145 of Steel and Torrie (1960).

Nitrogen response trials were a split-plot design with tillage being the mainplot factor and nitrogen fertilizer being the subplots factor (pages 232-241, Steel and Torrie 1960).

Greenhouse trials and vegetative dry weight development (1972) were organized as a completely randomized design and were analyzed accordingly (pages 101-105, Steel and Torrie 1960).

For statistical analysis, only the 5% level was considered meaningful.

RESULTS AND DISCUSSION

Comparisons between zero and conventional tillage were made over a three year period at three locations. The factors studied were weed populations, crop emergence, root development, soil moisture, yield, quality, soil fertility, and chemical weed control.

Soil physical properties data used to evaluate the crop response to the tillage treatments was obtained by Pakaranodom (1972).

Studies were conducted in the greenhouse to supplement field data on weed control.

A. Weed populations

The results of weed population studies are presented in Tables 4.1 to 4.21. The weed species which were present are indicated in Appendix D-2. The major weeds at each location were:

i/ Carman - green foxtail, wild oats, wild buckwheat, quack grass, and Canada Thistle.

ii/ Portage - green foxtail, wild oats and quack grass.

iii/ Sanford - green foxtail, green smartweed, and dandelion.

All weed counts and ratings on the large scale trials were based on an average of five subsamples per replication and six replications per treatment unless otherwise indicated in the tables.

a) <u>weed populations in 1969</u>

Total weed populations at the Carman location were slightly reduced under zero tillage (3.7 and 3.5 ratings) compared to the conventional treatment (5.1) (Table 4.1). Control with paraquat-diquat (ZT 1) and with paraquat-2,4-D ester (ZT 2) was similar. Green foxtail populations did not differ between treatments (Table 4.2). Wild buckwheat populations, Table 4.3, were slightly higher on the cultivated treatment (1.1 rating) than on the zero tillage treatments (0.8).

At Sanford, the average total weed populations were lower on the ZT 2 treatment (5.6 rating) than on ZT 1 (6.4) or cultivated treatments (6.6) (Table 4.1). The latter two treatments did not appear to differ. Green foxtail followed a pattern similar to the total weed populations (Table 4.2), as did smartweed, (Table 4.4) which made up a large proportion of the total weed population.

Weed counts at Portage indicated no significant differences. The weed infestation was very heavy and variable (Tables 4.5 to 4.8). Table 4.8 suggests that wild oats were reduced under zero tillage, relative to the cultivated treatment.

The data from Carman and Sanford indicated no differences in weed populations between crops. The only variable up to this time was crop competition which would not be expected to have an influence in the short time period involved (5 weeks). At Portage the differences between crops must have been due to the variability in the location. No comparisons between crops should be attempted in data for subsequent years from this location.

Table 4.1 Total weed populations under zero and conventional tillage prior to post-emergent herbicide application, 1969.

Location	Crop	Rating [a, b]		
		ZT 1	ZT 2	Cult
Carman	Wheat	3.4	3.3	4.2
	Barley	3.1	3.0	4.5
	Flax	4.6	4.1	6.7
	Rape	3.7	3.7	5.0
	Average	3.7	3.5	5.1
Sanford	Wheat	6.2	5.1	6.7
	Barley	6.2	5.6	6.4
	Flax	7.0	5.9	6.6
	Rape	6.2	5.8	6.7
	Average	6.4	5.6	6.6

a Individual weeds rated on a scale of 1 to 5. Total weed population ratings are a summation of individual weed ratings.

b Rating scheme: 1 = 1-5, 2 = 6-10, 3 = 11-15, 4 = 16-20, and 5 = 20+ weeds per 0.25 m^2. A summation of 7 indicates 31-35 weeds per 0.25 m^2. No statistical analysis was carried out on the ratings.

Table 4.2 Green foxtail populations under zero and conventional tillage prior to post-emergent herbicide application, 1969.

Location	Crop	Rating [a]		
		ZT 1	ZT 2	Cult
Carman	Wheat	1.9	2.0	1.9
	Barley	1.9	1.8	2.3
	Flax	2.1	1.8	2.4
	Rape	2.0	1.7	1.9
	Average	2.0	1.8	2.1
Sanford	Wheat	1.4	1.0	1.4
	Barley	1.4	1.0	1.3
	Flax	1.8	0.9	1.5
	Rape	1.5	1.1	1.5
	Average	1.5	1.0	1.4

a See note a, Table 4.1.

Table 4.3 Wild buckwheat populations under zero and conventional tillage prior to post-emergent herbicide application, Carman 1969.

Crop	Rating [a]		
	ZT 1	ZT 2	Cult
Wheat	0.9	0.9	1.1
Barley	0.8	0.8	1.3
Flax	1.0	0.8	1.2
Rape	0.4	0.5	0.8
Average	0.8	0.8	1.1

a See note a, Table 4.1.

Table 4.4 Smartweed [a] populations under zero and conventional tillage prior to post-emergent herbicide application, Sanford 1969.

Crop	Rating [b]		
	ZT 1	ZT 2	Cult
Wheat	4.6	4.1	4.7
Barley	4.2	4.0	4.5
Flax	4.9	4.2	4.4
Rape	4.4	3.6	4.5
Average	4.5	4.0	4.5

a Primarily *Polygonum scabrum* Moench with some *Polygonum persicaria* L.

b See note a, Table 4.1.

Table 4.5 Total weed populations under zero and conventional tillage prior to post-emergent herbicide application, Portage 1969.

Crop	Weed Counts [a] (per 0.25 m^2)			LSD (.05)
	ZT 1	ZT 2	Cult	
Wheat	94	74	84	ns
Barley	224	240	209	ns
Flax	237	203	258	ns
Rape	315	321	407	ns
Average	218	210	240	ns

a Based on an average of four replications per plot.

Table 4.6 Wild buckwheat populations under zero and conventional tillage prior to post-emergent herbicide application, Portage 1969.

Crop	Weed Counts [a] (per 0.25 m^2)			LSD (.05)
	ZT 1	ZT 2	Cult	
Wheat	2.0	2.2	2.1	ns
Barley	1.8	2.4	2.4	ns
Flax	2.3	1.2	3.3	ns
Rape	0.4	1.6	2.3	ns
Average	1.6	1.8	2.5	ns

a Based on an average of four replications per plot.

Table 4.7 Green foxtail populations under zero and conventional tillage prior to post-emergent herbicide application, Portage 1969.

Crop	Weed Counts [a] (per 0.25 m^2)			LSD (.05)
	ZT 1	ZT 2	Cult	
Wheat	71	54	45	ns
Barley	194	206	186	ns
Flax	185	169	211	ns
Rape	233	243	282	ns
Average	171	168	181	ns

a Based on an average of four replications per plot.

Table 4.8 Wild oat populations under zero and conventional tillage prior to post-emergent herbicide application, Portage 1969.

Crop	Weed Counts [a] (per 0.25 m^2)			LSD (.05)
	ZT 1	ZT 2	Cult	
Wheat	4.9	2.2	10.5	ns
Barley	13.3	10.7	13.6	ns
Flax	8.7	11.3	24.9	ns
Rape	7.7	15.4	22.4	ns
Average	8.6	9.9	17.9	ns

a Based on an average of four replications per plot.

b) <u>weed populations in 1970</u>

In the second year, weed counts were carried out at all locations, and significant differences were found.

At Carman, total weed numbers in flax were lower under cultivation (18.8) than ZT 2 (28.9) (Table 4.9). ZT 1 (22.3) was not different from the other two treatments. Green foxtail was lower in cultivated flax (11.7) than in zero tillage (19.8 and 23.2 for ZT 1 and ZT 2 respectively) (Table 4.10). The zero tillage treatments did not differ from each other. Green foxtail made up a major part of the total weed population. Wild oats followed the pattern which was noted at Portage in the first year (reduced under zero tillage), but differences were not significant (Table 4.11). Under zero tillage, wild buckwheat was reduced in wheat (57%) and rape (63%) at Carman, relative to cultivation (Table 4.12). In barley and flax wild buckwheat differences were not significant.

In flax and rape at Portage, total weed counts were higher in the cultivated treatment than in zero tillage treatments (Table 4.9). Total weed counts in flax at Portage indicated that only ZT 2 (25.4) was different from the cultivation treatment (43.3). Green foxtail was higher under cultivation than under zero tillage in flax and rape (Table 4.10). Wild oat counts were similar to those taken in 1969, where wild oats tended to be reduced under zero tillage (Table 4.11).

At Sanford, total weed numbers in wheat and rape were

Table 4.9 Total weed populations under zero and conventional tillage prior to post-emergent herbicide application, 1970.

Location	Crop	Weed Counts (per 0.25 m^2)			LSD (.05)
		ZT 1	ZT 2	Cult	
Carman	Wheat	14.5	16.8	19.6	ns
	Barley	15.2	19.1	16.3	ns
	Flax	22.3	28.9*	18.8	6.8
	Rape	13.9	18.4	17.7	ns
Portage	Wheat	35.5	31.5	48.6	ns
	Barley	43.1	33.1	68.3	ns
	Flax	35.9	25.4*	43.3	12.3
	Rape	35.8*	29.6*	77.0	37.9
Sanford	Wheat	51.5	27.4*	50.1	13.7
	Barley	56.6	53.6	51.4	ns
	Flax	59.3	56.3	58.0	ns
	Rape	75.2	49.9*	74.7	16.4

* Different compared to the cultivated treatment.

Table 4.10 Green foxtail populations under zero and conventional tillage prior to post-emergent herbicide application, 1970.

Location	Crop	Weed Counts (per 0.25 m^2)			LSD (.05)
		ZT 1	ZT 2	Cult	
Carman	Wheat	4.9	6.1	8.7	ns
	Barley	8.2	7.6	6.7	ns
	Flax	19.8*	23.2*	11.7	5.1
	Rape	8.9	13.8	10.9	ns
Portage	Wheat	21.5	19.0	28.7	ns
	Barley	30.3	20.8	42.3	ns
	Flax	23.2	18.0*	29.7	8.2
	Rape	22.8*	20.2*	66.4	35.8
Sanford	Wheat	25.5	11.8	12.8	ns
	Barley	27.3	26.7	18.3	ns
	Flax	20.0	20.5	11.3	ns
	Rape	31.5*	14.3	13.5	15.6

* Different compared to the cultivated treatment.

Table 4.11 Wild oat populations under zero and conventional tillage prior to post-emergent herbicide application, Carman and Portage, 1970.

Location	Crop	Weed Counts (per 0.25 m^2)			LSD (.05)
		ZT 1	ZT 2	Cult	
Carman	Wheat	0.5	2.1	0.9	ns
	Barley	0.5	3.2	1.5	ns
	Flax	0.1	1.6	1.8	ns
	Rape	0.4	2.3	1.6	ns
Portage	Wheat	2.6	3.5	7.5	ns
	Barley	2.8	7.9	12.3	ns
	Flax	9.1	4.8	11.3	ns
	Rape	8.3	6.1	7.4	ns

lower on ZT 2 than on ZT 1 or cultivation (Table 4.9). The paraquat-2,4-D ester mixture resulted in better control than the paraquat-diquat mixture. Total weed counts in flax at Portage also suggested this fact (Table 4.9). Green foxtail counts in rape at Sanford were higher on ZT 1 (31.5) than on the other treatments (14.3 and 13.5 for ZT 2 and cultivation respectively) (Table 4.10). Smartweed was the predominant weed at this location. Counts were higher under cultivated wheat and rape than under similar zero tillage crops (Table 4.13).

Table 4.12 Wild buckwheat populations under zero and conventional tillage prior to post-emergent herbicide application, Carman, 1970.

Crop	Weed Counts (per 0.25 m^2)			LSD (.05)
	ZT 1	ZT 2	Cult	
Wheat	2.6*	3.2*	6.0	1.9
Barley	2.9	3.9	5.1	ns
Flax	0.9	2.6	4.5	ns
Rape	1.5*	1.5*	4.1	2.1

* Different compared to the cultivated treatment.

Table 4.13 Smartweed [a] populations under zero and conventional tillage prior to post-emergent herbicide applications, Sanford, 1970.

Crop	Weed Counts (per 0.25 m^2)			LSD (.05)
	ZT 1	ZT 2	Cult	
Wheat	11.2*	8.7*	24.9	8.2
Barley	19.1	18.9	18.2	ns
Flax	33.7	30.9	37.9	ns
Rape	20.7*	18.3*	38.3	7.8

a Primarily *Polygonum scabrum* Moench with some *Polygonum persicaria* L.

* Different compared to the cultivated treatment.

The data from 1970 indicated that two years of zero tillage had an effect on the weed population. Differences between treatments did not consistently involve population reductions under zero tillage. On the Red River clay at Sanford, ZT 2, which contained 2,4-D ester, was more effective than ZT 1. This effect was less noticeable at Portage (clay loam) while no effect was apparent on the very fine sandy loam at Carman.

c) <u>weed populations in 1971</u>

During the third year differences in weed populations indicated more consistent reductions than in the previous year. There were no instances where weed counts were lower on the cultivated treatment, than on zero tillage, in 1971.

At Carman total weed counts in flax and rape were lower under both zero tillage treatments than under cultivation (Table 4.14). Green foxtail followed the same pattern as total weed counts (Table 4.15). This species constituted most of the total weed population at the Carman location. Wild oat counts were higher in cultivated flax and rape than on zero tillage (Table 4.16). On ZT 1, average counts were 0.1 and 0.3 wild oat plants/0.25 m^2 in flax and rape respectively, whereas counts under cultivation were 3.9 and 3.5 plants per 0.25 m^2. On this basis, wild oat control in zero tillage flax and rape was not required. Wild oat control was required on the cultivated treatment. Due to some wild oat patches on zero tillage,

Table 4.14 Total weed populations under zero and conventional tillage prior to post-emergent herbicide application, 1971.

Location	Crop	Weed Counts (per 0.25 m^2)			LSD (.05)
		ZT 1	ZT 2	Cult	
Carman	Wheat	166	148	246	ns
	Barley	195	124	188	ns
	Flax	49*	38*	191	71
	Rape	34*	37*	107	26
Portage	Wheat	209	162	213	ns
	Barley	478	437	259	ns
	Flax	231	125	141	ns
	Rape	99	119	226	ns
Sanford	Wheat	30	22	41	ns
	Barley	31	25*	42	10
	Flax	20*	11*	38	15
	Rape	30	27	34	ns

* Different compared to the cultivated treatment.

Table 4.15 Green foxtail populations under zero and conventional tillage prior to post-emergent herbicide application, 1971.

Location	Crop	Weed Counts (per 0.25 m^2)			LSD (.05)
		ZT 1	ZT 2	Cult	
Carman	Wheat	164	147	240	ns
	Barley	189	119	178	ns
	Flax	48*	35*	184	72
	Rape	31*	35*	97	25
Portage	Wheat	189	152	180	ns
	Barley	454	404	228	ns
	Flax	220	115	110	ns
	Rape	83	107	195	ns
Sanford	Wheat	7	3*	17	11
	Barley	12*	9*	19	6
	Flax	10	7	20	ns
	Rape	21	18	21	ns

* Different compared to the cultivated treatment.

Table 4.16 Wild oat populations under zero and conventional tillage prior to post-emergent herbicide applications, Carman and Portage, 1971.

Location	Crop	Weed Counts (per 0.25 m^2)			LSD (.05)
		ZT 1	ZT 2	Cult	
Carman	Wheat	0.1	0.4	3.2	ns
	Barley	0.2	0.4	3.5	ns
	Flax	0.1*	0.6*	3.9	3.1
	Rape	0.3*	0.6*	3.5	2.6
Portage	Wheat	4.7	6.9	16.5	ns
	Barley	3.0	2.8	16.0	ns
	Flax	7.4	4.5	15.2	ns
	Rape	11.8	10.2	27.4	ns

* Different compared to the cultivated treatment.

and to reduce variables between treatments, barban was applied to all treatments. Differences with wild buckwheat at Carman were found only in barley where higher counts were obtained under cultivation (2.4) than under zero tillage (0.6 and 0.4 for ZT 1 and ZT 2 respectively) (Table 4.17).

Total weed counts at Portage indicated no differences between treatments (Table 4.14). As in previous years, considerable variability existed at this site. Green foxtail, the major weed in terms of number of plants, followed the total weed count pattern (Table 4.15). Wild oat differences were not significant but in all crops, there was a tendency for counts to be higher on the cultivated treatment than on zero tillage treatments (Table 4.16). Figure 4.1 indicates the difference between a zero tillage and a cultivated plot.

At Sanford, total weed counts in barley and flax were higher under cultivation, relative to zero tillage (Table 4.14). In barley, only the ZT 2 treatment was different from cultivation. Green foxtail counts were higher under cultivation than under zero tillage in both cereal crops (Table 4.15). Smartweed counts were higher on the cultivated treatment for all crops (Table 4.18). In flax, ZT 2 (2.2) had a lower number of smartweed plants than ZT 1 (4.1). In 1971, ZT 2 was the paraquat-bromoxynil and MCPA mixture.

Third year data indicated that some annual grasses

Table 4.17 Wild buckwheat populations under zero and conventional tillage prior to post-emergent herbicide application, Carman 1971.

Crop	Weed counts (per 0.25 m^2)			LSD (.05)
	ZT 1	ZT 2	Cult	
Wheat	1.0	0.2	1.3	ns
Barley	0.6*	0.4*	2.4	1.7
Flax	1.0	1.3	1.8	ns
Rape	3.0	1.4	1.6	ns

* Different compared to the cultivated treatment.

Table 4.18 Smartweed [a] populations under zero and conventional tillage prior to post-emergent herbicide application, Sanford, 1971.

Crop	Weed Counts (per 0.25m^2)			LSD (.05)
	ZT 1	ZT 2	Cult	
Wheat	3.6*	4.5*	18.7	6.2
Barley	3.5*	4.9*	16.5	5.4
Flax	4.1*	2.2*	7.9	1.4
Rape	3.4*	2.2*	7.0	3.5

a Primarily *Polygonum scabrum* Moench with some *Polygonum persicaria* L.

* Different compared to the cultivated treatment.

Figure 4.1 Flax at Portage indicating differences in wild oat population in 1971. Left - cultivated; Right - zero tillage.

and broad-leaved weeds were reduced under zero tillage. Three years of zero tillage were sufficient to have a relatively consistent influence on the weed population.

d) perennial weeds

Perennial weed species, Canada thistle, dandelion, and quack grass, presented problems. Canada thistle and dandelion were controlled in the crop with selective herbicides. Dicamba, MCPA, and 2,4-D were used in cereals, and MCPA was used in flax. A fall treatment of dicamba was applied at Carman in 1969. In rapeseed, benazolin provided good suppression control of Canada thistle. The strong competition of the rapeseed crop combined with the growth retarding effect of benazolin on Canada thistle, resulted in good control.

Paraquat and strong crop competition kept quack grass in check. Quack grass was definitely the major weed problem. A herbicide which would be more effective on quack grass would be a definite asset to zero tillage crop production in Manitoba.

The perennial weed infestation was patchy and weed count data did not give a valid picture of the perennial weed population. General observations indicated that both perennial broad-leaved weeds and grasses were increasing under zero tillage. Quack grass patches became more dense, but spread slowly. The dense patches of quack grass had a detrimental influence on the crop stand.

The increase in the density of quack grass patches under zero tillage could possibly result in increased toxin production by decaying rhizomes. Also, if rhizomes were concentrated in the surface layer of soil under zero tillage, as has been reported by Schwerdtle (1970), the concentration of toxins could be increased. The toxin would be concentrated in the soil zone surrounding the seedling crop, and critical levels of toxin could be reached.

e) weed seed populations

Soil samples were taken in May of the third year to determine weed seed populations in the top 8 cm of soil. Tables 4.19 to 4.21 indicate that no significant differences were obtained. If the number of replications had been greater, significant differences might have been obtained. Sanford data showed a distinct trend. Also, a longer time period would more effectively indicate the influence of zero tillage on the weed seed populations.

At Carman, grasses tended to be present in lower numbers in zero tillage wheat (14) and rape (6) than in cultivated wheat (25) and rape (11) (Table 4.19). Broad-leaved weed numbers appeared higher in cultivated barley and flax than in comparable zero tillage crops. At Portage, the differences appeared to indicate fewer weed seeds in the cultivated treatment, but differences were inconsistent (Table 4.20). At Sanford, the tendency was for more weed seeds to be present in soil from the cultivated treatment than from the zero tillage treatments (Table 4.21).

f) <u>discussion of weed studies</u>

The results of this study are similar to the findings of Schwerdtle (1970). Annual broad-leaved weed populations were reduced under zero tillage. Annual grasses were not reduced to the same extent, while perennial weeds increased in the absence of tillage. Quack grass stand density increased in both studies.

Green foxtail populations increased on zero tillage in two instances in the second year (Carman flax and Sanford rape). This increase may have been due to seed

Table 4.19 Weed seedling emergence from soil samples taken May 1971, at Carman.

Species	Crop in 1971	Plants/Sample [a] ZT 1	Plants/Sample [a] Cult	LSD (.05)
Grasses	Wheat	14	25	ns
	Barley	18	13	ns
	Flax	7	6	ns
	Rape	6	11	ns
Broad-leaved Weeds	Wheat	2	1	ns
	Barley	1	4	ns
	Flax	3	4	ns
	Rape	1	2	ns
Total Weeds	Wheat	16	26	ns
	Barley	19	17	ns
	Flax	10	10	ns
	Rape	7	13	ns

a Based on two replications per plot and six plots per treatment.

Table 4.20 Weed seedling emergence from soil samples taken May 1971, at Portage.

Species	Crop in 1971	Plants/Sample [a] ZT 1	Plants/Sample [a] Cult	LSD (.05)
Grasses	Wheat	22	23	ns
	Barley	14	10	ns
	Flax	17	12	ns
	Rape	17	12	ns
Broad-leaved Weeds	Wheat	2	3	ns
	Barley	1	1	ns
	Flax	2	2	ns
	Rape	2	1	ns
Total Weeds	Wheat	24	27	ns
	Barley	15	11	ns
	Flax	18	14	ns
	Rape	19	12	ns

a Based on two replications per plot and six plots per treatment.

Table 4.21 Weed seedling emergence from soil samples taken May 1971, at Sanford.

Species	Crop in 1971	Plants/Sample [a]		LSD (.05)
		ZT 1	Cult	
Grasses	Wheat	11	15	ns
	Barley	8	21	ns
	Flax	8	20	ns
	Rape	13	16	ns
Broad-leaved Weeds	Wheat	9	17	ns
	Barley	11	14	ns
	Flax	4	6	ns
	Rape	3	8	ns
Total Weeds	Wheat	20	32	ns
	Barley	19	34	ns
	Flax	12	25	ns
	Rape	16	24	ns

a Based on two replications per plot and six plots per treatment.

accumulation on the soil surface under zero tillage. Green foxtail seed which remained in the surface soil layer germinated extensively the spring following seed production (over 98% of seeds sown germinated (Chepil 1946)). Peters (1972) claimed that no tillage resulted in seed accumulation on the soil surface and increased the number of seeds available for germination.

The effect of paraquat on grass seed germination which was noted by Appleby and Brenchley (1968), may have been effective in reducing green foxtail growth under zero tillage. There were several instances where green foxtail numbers were lower on zero tillage than on cultivation. Green foxtail counts at Sanford in 1970 indicated that 2,4-D ester may also have had an effect on green foxtail germination or emergence.

The reduction of the annual weed populations under zero tillage may have been due to weed seeds not being brought up to the germination zone. Soil compaction may have resulted in increased weed seed dormancy. Both of these factors were proposed by Robinson (1964).

Roberts and Dawkins (1967) found that the proportion of viable seeds giving rise to seedlings decreased from year to year under zero tillage, but the number of viable seeds did not decrease as rapidly as when the soil was cultivated. In this study, no differences in the viable seed population were found after two years, but fewer seedlings emerged under zero tillage.

The decrease in the wild oat population under zero tillage supported the findings of Cussans (1966) who found that seeds with pronounced dormancy, such as wild oats, are reduced by no-tillage. It is possible that paraquat had an effect on the exposed wild oat seed.

The arable and intermediate response weed groups proposed by Chancellor (1964) would be expected to decrease under zero tillage, while the inverse response group would be expected to increase in the absence of tillage. Very few of the species grouped by Chancellor were present in these trials. Lady's thumb (*Polygonum persicaria* L.) was in the intermediate response group. Green smartweed (*Polygonum scabrum* Moench) could be expected to respond similarily. This weed was reduced under zero tillage.

On the basis of these trials, green foxtail, wild oats, wild buckwheat and green smartweed should be placed in the arable or intermediate response groups. These species are problem weeds under Prairie conditions where tillage is limited (generally 2-4 operations per year), and therefore, would probably respond as intermediate response weeds.

Under zero tillage conditions, quack grass infestations increased in density. This increase in stand density, plus the potential toxin problem, indicate the importance of controlling quack grass under zero tillage. The recommendations of Robinson (1964) and Brown (1968) to avoid areas with perennial weed infestations cannot be considered as a solution to the quack grass problem. In Manitoba trials, paraquat retarded quack grass growth and allowed the crop to become established. A herbicide which could be used for zero tillage seedbed preparation, and which would control quack grass, would fit into a zero tillage program. Glyphosate could be used since it controlled annual weeds in a trial which will be discussed later, and controlled quack grass in Manitoba trials (Stobbe - unpublished data, University of Manitoba).

Where 2,4-D ester was used in combination with paraquat, weed control was less effective on the sandy soil (Carman), but more effective on the clay soil (Sanford), than a mixture of paraquat plus diquat. The addition of diquat to paraquat appeared to give better post emergent weed control than the addition of 2,4-D ester to paraquat. Two,4-D ester appeared to give some soil residual control depending on the clay content of the soil.

The data from 1969 to 1971 indicated that during the initial years, zero tillage resulted in inconsistent decreases in the annual weed population. As the time period increased, more consistent and pronounced differences developed. Perennial weeds were a problem under zero tillage.

Paraquat at rates used in this experiment would not make zero tillage commercially viable. Alternate herbicides or mixtures tested in Manitoba are dealt with in a subsequent section.

B. Crop emergence

Crop emergence counts were recorded during the three year period. Data is summarized in Tables 4.22 to 4.25. Row spacings were changed from 15 cm in 1969 to 18 cm in 1970 and 1971. This change in row spacing accounted for lower emergence counts in 1969 since the same seeding rates (kg/ha) were used each year. All emergence counts are the average of four subsamples per replication and six replications per treatment.

The number of seeds in 1.5 meters of row are tabulated in Appendix C-2 for evaluation of percent emergence.

The data indicated that emergence was significantly different at only one location in the first year. At Carman, wheat emergence (Table 4.22) was lower (16%) on zero tillage than on cultivation. Barley showed no emergence differences (Table 4.23). Flax and rape emergence was lower under ZT 2, paraquat plus 2,4-D ester, than under ZT 1 or cultivation (Tables 4.24 and 4.25).

In the second year, emergence on the cultivated treatment was lower than on zero tillage for all crops and locations except one. Emergence of barley at Portage did not differ between treatments (Table 4.23). For wheat and barley, the two zero tillage treatments did not differ (Tables 4.22 and 4.23). Flax and rape emergence at Sanford (Red River clay) was lower on ZT 2 than

Table 4.22 Emergence of wheat (plants per 1.5 m of row) under zero and conventional tillage.

Year	Location	Treatment			LSD (.05)
		ZT 1	ZT 2	Cult	
1969	Carman	44*	42*	51	6.5
	Portage	60	64	62	ns
	Sanford	42	38	43	ns
1970	Carman	60*	56*	49	4.5
	Portage	61*	61*	52	4.4
	Sanford	57*	55*	45	6.8
1971	Carman	65*	67*	51	5.8
	Portage	65*	64*	57	4.4
	Sanford	58	58	59	ns

* Different compared to the cultivated treatment.

Table 4.23 Emergence of barley (plants per 1.5 m of row) under zero and conventional tillage.

Year	Location	Treatment			LSD (.05)
		ZT 1	ZT 2	Cult	
1969	Carman	32	32	33	ns
	Portage	40	46	41	ns
	Sanford	28	25	28	ns
1970	Carman	27*	27*	22	2.9
	Portage	27	26	26	ns
	Sanford	34*	35*	28	2.5
1971	Carman	58	58	51	ns
	Portage	58*	57*	48	4.0
	Sanford	70	69	75	ns

* Different compared to the cultivated treatment.

Table 4.24 Emergence of flax (plants per 1.5 m of row) under zero and conventional tillage.

Year	Location	Treatment			LSD (.05)
		ZT 1	ZT 2	Cult	
1969	Carman	95	73*	86	12.4
	Portage	87	87	106	ns
	Sanford	75	74	76	ns
1970	Carman	118*	112*	87	17.7
	Portage	132*	128*	90	13.1
	Sanford	108*	85	75	11.3
1971	Carman	176*	176*	77	12.9
	Portage	193*	182*	115	22.0
	Sanford	161	144	164	ns

* Different compared to the cultivated treatment.

Table 4.25 Emergence of rape (plants per 1.5 m of row) under zero and conventional tillage.

Year	Location	Treatment			LSD (.05)
		ZT 1	ZT 2	Cult	
1969	Carman	37	26*	34	4.2
	Portage	54	49	43	ns
	Sanford	24	20	22	ns
1970	Carman	11*	10*	8	1.9
	Portage	24*	20*	16	3.5
	Sanford	49*	34	33	6.0
1971	Carman	58	54	49	ns
	Portage	55*	42*	36	3.3
	Sanford	57	50	56	ns

* Different compared to the cultivated treatment.

on ZT 1, and not different from cultivation (Table 4.24). In rape at Portage, differences existed between all three treatments, with cultivation (16) being less than ZT 2 (20) which was less than ZT 1 (24) (Table 4.25).

The 2,4-D effect (reduced emergence) was more pronounced on the heavy clay soil than on the clay loam (Table 4.25). In 1970, no effect was noticeable on the very fine sandy loam. In 1969, reduction of ZT 2 rape at Carman was observed. A similar effect was noticed in the weed population data.

In the third year, wheat emergence was better under zero tillage (ZT 1 and ZT 2) than under cultivation at Carman and Portage, and not different at Sanford (Table 4.22). Barley emergence was 21% higher under zero tillage, relative to conventional tillage, at Portage (Table 4.23). No differences in barley emergence were noted at Carman and Sanford.

Flax emergence under zero tillage was better than under cultivation at Carman and Portage, while, at Sanford, no differences were present (Table 4.24). This was similar to wheat emergence in 1971. Rape emergence at Portage was lower under cultivation (36) than under ZT 1 (55) or ZT 2 (42) (Table 4.25). Rape emergence on ZT 2 was lower than on ZT 1, even though 2,4-D ester was not used in 1971. Possibly, bromoxynil plus MCPA had some effect on rape emergence.

The spring of 1969 was abnormally wet. This prevented the moisture conservation characteristic of zero tillage from resulting in improved emergence. The moist soil was disturbed by the triple disc drill. This was probably the main reason why emergence percentage was relatively low in the first year.

Pakaranodom (1972), working on the same trials, found an increase in surface soil moisture under zero tillage. The effect of soil moisture on percent total germination was noted only at water potentials of less than pF 4.31 (Owens 1952). However, under high soil moisture conditions the rate of germination increased (Williams and Shaykewich 1971 and Owens 1952). Low soil moisture resulted in uneven germination (Williams and Shaykewich 1971 and Collis-George and Sands 1959).

Pakaranodom (1972) found reduced soil aeration (air filled porosity, total porosity, and oxygen diffusion rate) in the 0-8 cm layer of soil. He stated that the values for zero tillage were not below the reported critical values. The crop emergence data supported the fact that aeration was not a limiting factor. Soil temperature was not reduced in this trial (Pakaranodom 1972) but readings were not taken at or before time of seeding. Friesen and Bonnefoy (1973) found no temperature changes resulting from fall tillage in Manitoba.

The emergence data indicated an advantage for zero tillage crop production. In wet years the increased emergence may not be observed. Flax emergence responded most favorably to zero tillage. Rape emergence was superior under zero tillage. The critical depth of seeding, germination moisture content, and firm seedbed requirement support the zero tillage treatment for these crops. The cereals have a lower germination moisture content, are seeded deeper, and grow well in a loose seedbed. However, emergence of cereals was still superior under zero tillage.

The triple disc drill system proved to be satisfactory for Manitoba soils. Some problems were encountered when the soil was moist.

The residual 2,4-D effect eliminated this mixture even though weed control was frequently better on the heavier soils. This aspect would not prevent its use in cereal crop production. The fact that the 2,4-D effect was apparent on the lighter soil only in the first year suggests that soil moisture has an influence on the 2,4-D residue-soil texture interaction. Soil moisture data for 1969 was not recorded.

C. Seedling growth and development

Zero tillage crop stands appeared to be more dense than comparable cultivated crops. Dry weight determinations were made in all crops on June 28, 1971, 6 weeks after seeding (Table 4.26). No crop showed differences at all three locations when sampled on this date. All differences present indicated greater dry weights on zero

Table 4.26 Seedling dry weight on June 28, 1971.

Crop	Location	Dry Wt. (g/0.5 m of row) ZT 1	Cult	LSD (.05)
Wheat	Carman	23.0*	14.0	7.7
	Portage	10.9	7.6	ns
	Sanford	14.0*	10.7	2.7
Barley	Carman	24.0	27.6	ns
	Portage	12.8	10.1	ns
	Sanford	27.9*	19.9	6.8
Flax	Carman	9.3	8.5	ns
	Portage	6.3*	3.2	0.6
	Sanford	7.4*	4.7	0.6
Rape	Carman	20.9	20.7	ns
	Portage	8.4*	6.0	2.3
	Sanford	17.5	10.5	ns

* Different compared to the cultivated treatment.

than on conventional tillage. Figure 4.2 shows zero and conventional tillage wheat at 4 weeks after seeding.

In 1972, trials were conducted to determine dry weight development of wheat, barley, and rape at two week intervals after emergence. Results presented in Table 4.27 indicate greater early growth on zero tillage, relative to cultivation, for all crops. The cereal crops exhibited greater differences than did rapeseed.

Table 4.28 indicates more plants emerging under zero tillage for barley and rape. Wheat emergence was similar under both treatments.

Calculated individual plant weights (Table 4.29) indicate that the cereal plants grown under zero tillage were larger than plants from the cultivated treatment. Individual plant weights for rape showed no differences. Rape is a crop where a reduced stand density is generally compensated for by an increase in plant size. Under zero tillage, when the number of plants was increased, plant size was maintained, resulting in an increased total dry weight. For barley, a combination of increased plant numbers and increased plant size resulted in the total dry weight difference. Wheat differences were the result of increased plant size. Barley exhibited the greatest differences, based on zero tillage as a percent of cultivation, followed by wheat and then rape.

Increased rate of growth for corn on zero tillage has been reported by Moody _et al_. (1961). In contrast,

Figure 4.2 Zero tillage (upper) and conventional tillage (lower) wheat four weeks after seeding.

Table 4.27 Seedling dry weight (g/30 cm of row) under zero[a] and conventional tillage at Carman, 1972.

Crop	Weeks After Emergence	ZT	Cult	LSD (.05)
Wheat	2	1.1*	0.6	0.2
	4	6.0*	3.0	1.6
	6	25.5*	12.8	4.9
	8	40.8*	23.6	6.2
Barley	2	3.1*	0.7	0.3
	4	17.2*	6.2	2.5
	6	38.9*	18.7	5.3
	8	49.6*	31.2	7.5
Rape	2	1.6*	0.4	0.5
	4	10.5*	5.4	3.7
	6	15.1	16.3	ns
	8	24.2*	19.1	3.2

a Zero tillage plots in fourth year of zero tillage management.

* Different compared to the cultivated treatment.

Table 4.28 Number of plants (plants/30 cm of row) under zero [a] and conventional tillage at Carman, 1972.

Crop	Weeks After Emergence	ZT	Cult	LSD (.05)
Wheat	2	13.0	11.0	ns
	4	14.3	13.7	ns
Barley	2	19.7*	13.0	4.4
	4	14.3*	11.7	2.1
Rape	2	18.3*	10.0	6.3
	4	20.3*	7.7	9.4

a Zero tillage plots in fourth year of zero tillage management.

* Different compared to the cultivated treatment.

Table 4.29 Plant weight (g/plant) under zero [a] and conventional tillage at Carman, 1972.

Crop	Weeks After Emergence	ZT	Cult	LSD (.05)
Wheat	2	0.09*	0.05	.02
	4	0.42*	0.22	.10
Barley	2	0.16*	0.06	.03
	4	1.20*	0.52	.33
Rape	2	0.09	0.04	ns
	4	0.51	0.69	ns

a Zero tillage plots in fourth year of zero tillage management.

* Different compared to the cultivated treatment.

Heinonen (1968) reported poor initial development of rape on zero tillage.

D. Root development

Preliminary studies in 1970 indicated that root development was not inhibited under zero tillage. Detailed studies were conducted in the third year.

Root weights from Carman samples are presented in Tables 4.30 and 4.31. The only difference was for rape where more roots were present from 61-76 cm under zero tillage than under conventional tillage. The general trend was for root weights to be higher under zero tillage but differences were not significant. At Carman root development was not inhibited by zero tillage.

Barley at Sanford exhibited 5 cm greater root penetration under zero tillage (Table 4.32). At Portage and Sanford a trend towards greater root development occurred under zero tillage wheat, flax, and rape but differences were not significant. At Portage, barley roots tended to penetrate better on the cultivated treatment (90 cm) than on zero tillage (86 cm).

At Portage, some rape root samples from the cultivated treatment contained tap roots which turned horizontally when an apparently compacted soil layer was encountered. This is illustrated in Figure 4.3. Under zero tillage, no such root samples were obtained. This suggested that a tillage pan existed under cultivation, but by the third year

Table 4.30 Root weights of wheat and barley under zero and conventional tillage at Carman, July 8, 1971.

Crop	Depth (cm)	Root Weight ($g/102\ cm^2$)		LSD (.05)
		ZT 1	Cult	
Wheat	15 - 30	0.113	0.101	ns
	30 - 46	0.067	0.068	ns
	46 - 61	0.070	0.046	ns
	61 - 76	0.051	0.034	ns
	76 - 91	0.028	0.016	ns
	91 - 108	0.011	0.007	ns
	Total	0.340	0.272	ns
Barley	15 - 30	0.163	0.173	ns
	30 - 46	0.078	0.139	ns
	46 - 61	0.056	0.091	ns
	61 - 76	0.036	0.041	ns
	76 - 91	0.023	0.020	ns
	91 - 108	0.010	0.007	ns
	Total	0.365	0.470	ns

Table 4.31 Root weights of rape (July 9) and flax (July 14) under zero and conventional tillage at Carman, 1972.

Crop	Depth (cm)	Root Weight (g/102 cm^2)		LSD (.05)
		ZT 1	Cult	
Rape	15 - 30	0.104	0.104	ns
	30 - 46	0.072	0.079	ns
	46 - 61	0.071	0.042	ns
	61 - 76	0.041*	0.022	.018
	76 - 91	0.033	0.012	ns
	91 - 108	0.009	0.002	ns
	Total	0.329	0.260	ns
Flax	15 - 30	0.111	0.156	ns
	30 - 46	0.084	0.071	ns
	46 - 61	0.077	0.047	ns
	61 - 76	0.046	0.029	ns
	76 - 91	0.024	0.010	ns
	91 - 108	0.008	0.008	ns
	Total	0.349	0.320	ns

* Different compared to the cultivated treatment.

Table 4.32 Root penetration under zero and conventional tillage at Portage (July 21-23) and Sanford (August 4-6) 1972.

Location	Crop	Penetration (cm)		LSD (.05)
		ZT 1	Cult	
Portage	Wheat	86	79	ns
	Barley	86	90	ns
	Rape	97	88	ns
	Flax	82	79	ns
Sanford	Wheat	99	86	ns
	Barley	95*	90	4.3
	Rape	100	94	ns
	Flax	96	91	ns

* Different compared to the cultivated treatment.

Figure 4.3 Tap root of a rapeseed plant in a soil core taken from a cultivated treatment plot at Portage.

of zero tillage, the resistance to rooting presented by this tillage pan had decreased.

When core samples were taken at all three locations, it was apparent that the tillage pan which was present in cultivated plots was less prominent on zero tillage plots. This fact was not reported by Pakaranodom (1972) who worked on the same trials. He reported a higher soil strength under zero tillage.

Root development was not restricted under zero tillage at any location or with any crop. It appeared that root penetration was slightly superior under zero tillage than under cultivation.

E. Soil moisture

Soil moisture samples were taken in conjunction with root development samples at all locations. Soil moisture in the upper 15 cm of soil in these trials was determined by Pakaranodom (1972). At Carman in 1971, Pakaranodom (1972) found a greater moisture content (% of dry weight) in the 0-8 cm layer under zero tillage than under conventional tillage, when growing season averages were considered. The first measurement was taken on July 8. The largest differences would be expected early in the growing season. Also, moisture content differences in this layer would exert their greatest influence on the germination and seedling growth stages.

Pakaranodom (1972) stated that although only one significant difference was found at Carman during the two years, 1970 and 1971, soil moisture in the 0-15 cm layer tended to be greater under zero tillage. At Portage, moisture content tended to be higher under zero tillage in 1970 and higher under cultivation in 1971, while at Sanford soil moisture tended to be higher under zero tillage in both years (Pakaranodom 1972).

Pakaranodom (1972) concluded that soil moisture was higher under zero tillage, relative to conventional tillage. However, his data was limited to the surface soil and excluded early season data. The influence of moisture from this zone would be greatest at the time of seeding and seedling growth. Rootbed moisture would exert a greater influence as crop growth progressed.

Tables 4.33 and 4.34 indicate moisture content of the soil profile at Carman near the middle of July (shortly after heading). The only difference indicated that soil moisture at the 30 cm depth was greater for rape on zero tillage (20.8%) than for rape on conventional tillage plots (17.0%).

At Portage (Tables 4.35 and 4.36), soil moisture content for wheat and flax indicated no differences between treatments. Rape under zero tillage had 4.5% (% of dry wt.) more moisture at the 15 cm depth than did rape under cultivation. Soil moisture under barley exhibited the largest differences between treatments (Table 4.35). Soil moisture under zero tillage was greater at the 15, 46, and

Table 4.33 Soil moisture content at Carman under zero and conventional tillage in wheat and barley, July 8, 1971.

Crop	Depth (cm)	Soil Moisture (% by wt.)		LSD (.05)
		ZT 1	Cult	
Wheat	15	22.8	21.8	ns
	30	21.5	17.9	ns
	46	20.9	18.5	ns
	61	21.4	20.5	ns
	91	26.8	26.1	ns
	Average	22.6	20.9	ns
Barley	15	22.5	21.0	ns
	30	20.8	17.3	ns
	46	20.8	17.5	ns
	61	20.2	20.8	ns
	91	22.1	26.7	ns
	Average	21.3	20.6	ns

Table 4.34 Soil moisture content at Carman under zero and conventional tillage in rape (July 9) and flax (July 14) 1971.

Crop	Depth (cm)	Soil Moisture (% by wt.)		LSD (.05)
		ZT 1	Cult	
Rape	15	22.4	21.7	ns
	30	20.8*	17.0	2.5
	46	19.6	19.1	ns
	61	21.6	21.4	ns
	91	24.6	26.1	ns
	Average	21.7	21.3	ns
Flax	15	22.5	21.6	ns
	30	20.4	19.3	ns
	46	21.0	19.0	ns
	61	22.3	20.8	ns
	91	26.6	29.0	ns
	Average	22.5	21.9	ns

* Different compared to the cultivated treatment.

Table 4.35 Soil moisture content at Portage under zero and conventional tillage in wheat and barley, July 21-22, 1971.

Crop	Depth (cm)	Soil Moisture (% by wt.)		LSD (.05)
		ZT 1	Cult	
Wheat	15	21.3	20.6	ns
	30	20.3	20.2	ns
	46	18.2	19.5	ns
	61	20.3	17.5	ns
	91	21.5	17.0	ns
	Average	20.3	18.9	ns
Barley	15	24.8*	18.0	6.5
	30	22.4	19.7	ns
	46	22.6*	16.6	2.0
	61	20.4*	15.2	1.7
	91	20.4	21.5	ns
	Average	22.0*	18.2	3.4

* Different compared to the cultivated treatment.

Table 4.36 Soil moisture content at Portage under zero and conventional tillage in rape and flax, July 22-23, 1971.

Crop	Depth (cm)	Soil Moisture (% by wt.)		LSD (.05)
		ZT 1	Cult	
Rape	15	22.2*	17.7	3.9
	30	24.6	26.5	ns
	46	23.3	23.4	ns
	61	20.9	17.8	ns
	91	20.2	17.3	ns
	Average	22.2	20.5	ns
Flax	15	14.6	15.3	ns
	30	18.6	19.9	ns
	46	15.8	17.5	ns
	61	14.3	15.7	ns
	91	15.5	14.5	ns
	Average	15.8	16.5	ns

* Different compared to the cultivated treatment.

61 cm depths. Average moisture content for the profile was 3.8% greater under zero tillage than under conventional tillage.

Results at Sanford (Tables 4.37 and 4.38) indicated only one difference. Wheat under cultivation had more soil moisture at the 30 cm depth than did wheat under zero tillage. At this date Pakaranodom (1972) found greater soil moisture in the upper 15 cm under zero tillage than under conventional tillage.

Soil moisture results indicated that few differences between treatments could be detected at a stage beyond the most critical period. The critical stage for cereals has been shown to be at the time of heading (Lehane and Staple 1962).

This data does not indicate that differences were absent earlier in the growing season. Greater vegetative growth would have increased water requirements. Some of this water may have come from the upper soil layer during early growth stages.

Increased soil moisture under zero tillage has been reported by many workers (Blevins *et al*. 1971, Jones *et al*. 1968, Lillard and Jones 1964, Moody *et al*. 1964, Moschler *et al*. 1969, Shanholtz and Lillard 1961, and Triplett *et al*. 1964).

F. Moisture stress

In 1970, relative moisture stress readings in wheat,

Table 4.37 Soil moisture content at Sanford under zero and conventional tillage in wheat and barley, August 4, 1971.

Crop	Depth (cm)	Soil Moisture (% by wt.)		LSD (.05)
		ZT 1	Cult	
Wheat	15	22.2	17.3	ns
	30	18.0*	22.7	3.7
	46	23.1	26.4	ns
	61	22.6	23.5	ns
	91	25.0	19.1	ns
	Average	22.2	21.8	ns
Barley	15	22.7	21.3	ns
	30	20.7	18.6	ns
	46	23.3	23.7	ns
	61	21.6	22.4	ns
	91	18.9	19.8	ns
	Average	20.9	21.5	ns

* Different compared to the cultivated treatment.

Table 4.38 Soil moisture content at Sanford under zero and conventional tillage in rape and flax, August 6, 1971.

Crop	Depth (cm)	Soil Moisture (% by wt.)		LSD (.05)
		ZT 1	Cult	
Rape	15	18.0	19.2	ns
	30	19.2	20.7	ns
	46	26.5	23.5	ns
	61	25.2	26.0	ns
	91	23.3	18.2	ns
	Average	22.5	21.5	ns
Flax	15	20.3	21.1	ns
	30	26.7	21.2	ns
	46	20.2	22.2	ns
	61	24.8	30.9	ns
	91	22.1	25.3	ns
	Average	22.9	24.1	ns

obtained by the pressure bomb technique, indicated a lower moisture stress under zero tillage than under cultivation, from the two to six leaf stages. In 1971, wheat and barley showed no differences at any stage. Relative turgidity measurements in rape and flax showed no differences between treatments.

Since the only differences were at an early stage (2-6 leaf stage), and since the crop response differences did not correspond with the differences in relative moisture stress, this data is not included.

G. Yield, yield components, and determinations on seed samples

a) yield

Yield results are presented in Tables 4.39 to 4.42. The only yield difference for the cereal crops was with barley in the third year at Carman, where the yield under cultivation was 25% greater than the yield under zero tillage (Table 4.40).

Flax yielded higher under zero tillage in three instances, at Sanford in 1970 and 1971, and at Portage in 1971. Yield on ZT 1 increased (difference as a percent of yield under cultivation) by 16, 30, and 26 percent for Sanford 1970, Sanford 1971, and Portage 1971 respectively.

Yields of rape indicated one difference, at Sanford in 1970, where yield on ZT 1 was increased by 99 percent (difference as a percent of yield under cultivation).

Table 4.39 Grain yield of wheat under zero and conventional tillage.

Year	Location	Yield (kg/ha)			LSD (.05)
		ZT 1	ZT 2	Cult	
1969	Carman	2654	2580	2392	ns
	Portage	2896	2796	2414	ns
	Sanford	965	1021	765	ns
1970	Portage	1996	2009	1929	ns
	Sanford	2106	2284	2003	ns
1971	Carman	2634	2715	2547	ns
	Portage	1620	1673	1438	ns
	Sanford	1781	1949	1996	ns

Table 4.40 Grain yield of barley under zero and conventional tillage.

Year	Location	Yield (kg/ha)			LSD (.05)
		ZT 1	ZT 2	Cult	
1969	Carman	2905	3034	2954	ns
	Portage	2513	2518	2421	ns
	Sanford	462	605	503	ns
1970	Portage	2141	2114	1818	ns
	Sanford	2813	3163	3287	ns
1971	Carman	2448*	2389*	3067	376
	Portage	1953	1931	1953	ns
	Sanford	2911	3088	3228	ns

* Different compared to the cultivated treatment.

Table 4.41 Seed yield of flax under zero and conventional tillage.

Year	Location	Yield (kg/ha)			LSD (.05)
		ZT 1	ZT 2	Cult	
1969	Carman	903	878	759	ns
	Portage [a]	351	395	320	ns
	Sanford	597	513	798	ns
1970	Portage [a]	575	615	433	ns
	Sanford	991*	1072*	853	82
1971	Carman	865	677	759	ns
	Portage [a]	984*	947*	784	159
	Sanford	1135*	1122*	872	103

a Based on an average of four replications due to severe wild oat infestation on two replicates.

* Different compared to the cultivated treatment.

Table 4.42 Seed yield of rape under zero and conventional tillage.

Year	Location	Yield (kg/ha)			LSD (.05)
		ZT 1	ZT 2	Cult	
1969	Carman	682	798	600	ns
	Portage	1535	1381	1227	ns
	Sanford	579	610	577	ns
1970	Portage	605	523	347	ns
	Sanford	930*	649	468	226
1971	Carman	792	902	990	ns
	Portage	1513	1403	1320	ns

* Different compared to the cultivated treatment.

In this instance, yield on ZT 2 was lower than yield on ZT 1. This difference can be attributed to the residual 2,4-D effect which was mentioned previously.

The yield results indicated that cereal yields generally did not differ between treatments under the conditions of this experiment. The small seeded crops (rape and flax) yielded higher in some instances under zero tillage than under cultivation. A herbicide mixture containing 2,4-D would not be advisable for rape, especially on the heavier soils. The yield reduction for barley under zero tillage will be discussed after the protein contents have been included.

b) <u>bushel weight and moisture content (maturity)</u>

Bushel weight determinations were conducted on all harvested samples. No differences between treatments were found over the three year period. Moisture content of harvested samples was determined in the second and third years. The only significant difference was for barley at Portage in 1971 where moisture content was lower under zero tillage than under cultivation (Table 4.43). When yield results were corrected for moisture content (Table 4.43), there were still no yield differences between treatments.

Barley at Portage in 1971 was harvested as early as possible, and rainfall was not an immediate factor in grain moisture content. Differences in maturity (moisture content) were evident. With barley at other locations,

Table 4.43 Moisture content, yield, and 0% moisture yield of barley at Portage in 1971.

Treatment	Moisture Content (% of wet weight)	Yield (kg/ha)	
		At Harvested Moisture Content	0% Moisture
ZT 1	15.0*	1953	1662
ZT 2	14.8*	1931	1641
Cult	16.6	1953	1630
LSD (.05)	1.0	ns	ns

* Different compared to the cultivated treatment.

and with wheat at all locations, head samples were taken prior to harvest to evaluate maturity (Table 4.44). Maturity of cereals at Carman and Portage was more advanced under zero tillage than under conventional tillage. Maturity did not differ between treatments at Sanford.

c) <u>kernel weight</u>

Kernel weight determinations for 1970 showed no differences between treatments. Some differences were observed in the third year (Table 4.45). Barley kernel weight at Portage was reduced under zero tillage, even after kernel weights were corrected to 0% moisture. Rape under zero tillage at Carman had a greater kernel weight than did rape under cultivation. Flax on ZT 2 at Carman

Table 4.44 Head moisture content of wheat and barley prior to harvest.

Crop	Location	Date	Moisture Content (% of fresh wt.)[a] ZT 1	Cult	LSD (.05)
Wheat	Carman	9/8/71	51.2*	57.8	1.9
	Portage	31/8/71	26.6*	29.7	2.8
	Sanford	9/8/71	52.3	52.8	ns
Barley	Carman	9/8/71	20.6*	36.8	6.4
	Sanford	9/8/71	29.7	35.6	ns

a Based on an average of 6 replicated samples of 100 heads.

* Different compared to the cultivated treatment.

Table 4.45 Kernel weight under zero and conventional tillage, 1971.

Crop	Location	1000 Kernel Wt. (g)			LSD (.05)
		ZT 1	ZT 2	Cult	
Wheat	Carman	30.0	30.2	29.6	ns
	Portage	30.1	30.4	30.4	ns
	Sanford	32.3	33.4	33.3	ns
Barley	Carman	36.3	36.1	36.0	ns
	Portage	35.9*	37.2	39.0	1.5
	Sanford	36.1	36.4	37.6	ns
Flax	Carman	5.1	5.3	5.2	ns
	Portage [a]	5.3	5.1	5.4	ns
	Sanford	5.2	5.6*	5.3	0.29
Rape	Carman	8.0*	8.0*	7.4	0.4
	Portage	7.4	6.9	6.8	ns

* Different compared to the cultivated treatment.

a Based on an average of four replications.

had a higher kernel weight than flax on ZT 1 or cultivated plots.

d) oil content

Oil content analysis was conducted on flax and rape seed samples from 1970. Results are summarized in Table 4.46. No differences were found. Refractive index of oil samples indicated no differences between treatments.

e) protein content

Protein content determinations from 1970 samples are presented in Table 4.47. Protein was lower for wheat under zero tillage than for wheat under cultivation at Portage. Yield differences were not significant, but tended to be slightly higher for zero tillage.

Protein contents in 1971 are presented in Table 4.48. Barley at Carman had a lower protein content under zero tillage than under conventional tillage. Yield of barley at this location was higher under cultivation. The decreased protein content and decreased yield under zero tillage suggested a nitrogen deficiency. The earlier maturity of crops (Tables 4.43 and 4.44) also suggested a nitrogen deficiency under zero tillage, although this could have been due to more rapid growth in the absence of tillage.

f) tiller development

The number of fertile tillers produced by wheat and barley under zero and conventional tillage is given in Tables 4.49 to 4.51.

Table 4.46 Oil content of flax and rape under zero and conventional tillage, 1970.

Crop	Location	Oil Content (%)		LSD (.05)
		ZT 1	Cult	
Flax	Portage [a]	41.4	42.7	ns
	Sanford	42.7	42.4	ns
Rape	Portage	47.8	47.7	ns
	Sanford	46.5	47.2	ns

a Based on an average of four replications.

Results from Carman in 1970 are missing due to hail damage. Results from Portage in 1969 were recorded on the basis of tillers per plant, and therefore are reported separately (Table 4.51). No emergence differences were shown at Portage in the first year.

Fertile tiller counts, except for Portage, 1969, are based on an average of four subsamples per replication and six replications per treatment.

In general no differences existed. The only significant difference was in wheat at Sanford in the third year (Table 4.49), where tillering was reduced under cultivation.

Since wheat and barley yields were similar under zero

Table 4.47 Protein content of wheat and barley under zero and conventional tillage, 1970.

Crop	Location	Protein Content [a]		LSD (.05)
		ZT 1	Cult	
Wheat	Portage	14.5*	16.0	1.2
	Sanford	15.2	16.0	ns
Barley	Portage	10.7	11.5	ns
	Sanford	11.4	11.4	ns

a N x 6.25 on a 0% moisture basis.

* Different compared to the cultivated treatment.

and conventional tillage, tillering, one of the three yield components, was not expected to differ between treatments.

At Carman, when barley yield under zero tillage was reduced (Table 4.40), a yield component other than tillering must have varied between treatments. Kernel weight was lower under zero tillage than under cultivation (Table 4.45). The other yield component which could have varied was kernels per head.

g) kernels per head

In 1971, kernels per head counts were conducted so that the three components which constitute yield of cereals

Table 4.48 Protein content of wheat and barley under zero and conventional tillage, 1971.

Crop	Location	Protein Content			LSD (.05)
		ZT 1	ZT 2	Cult	
Wheat [a]	Carman	13.3	13.8	14.1	ns
	Portage	14.0	13.9	13.8	ns
	Sanford	13.4	13.4	13.5	ns
Barley [b]	Carman	11.1	10.7*	11.3	0.4
	Portage	10.3	10.4	10.3	ns
	Sanford	11.1	10.8	10.6	ns

a N x 5.7 on a 0% moisture basis.

b N x 6.25 on a 0% moisture basis.

* Different compared to the cultivated treatment.

would be known (Table 4.52). The number of kernels per head of wheat did not differ between tillage treatments (ZT 1 and Cult) but the number of kernels per head of barley was lower under zero tillage (ZT 1) than under conventional tillage at Carman and Portage. In barley at Sanford, the two treatments did not differ in the number of kernels per head.

Table 4.49 Fertile tillers of wheat (tillers per 1.5 m of row) under zero and conventional tillage.

Year	Location	Treatment			LSD (.05)
		ZT 1	ZT 2	Cult	
1969	Carman	114	117	117	ns
	Sanford	99	99	99	ns
1970	Portage	98	103	92	ns
	Sanford	85	87	95	ns
1971	Carman	122	118	122	ns
	Portage	114	109	98	ns
	Sanford	103*	109*	92	2

* Different compared to the cultivated treatment.

h) <u>discussion of yield components</u>

For wheat, the only yield component that differed between ZT 1 and cultivation was the number of fertile tillers produced per unit of area at Sanford. The ZT 1 treatment had 103 fertile tillers per 1.5 meters of row while the cultivated treatment had 92 fertile tillers in 1.5 meters of row. The ZT 2 treatment had 109 fertile tillers in 1.5 meters of row. Yield, kernel weight, and

Table 4.50 Fertile tillers of barley (tillers per 1.5 m of row) under zero and conventional tillage.

Year	Locations	Treatment			LSD (.05)
		ZT 1	ZT 2	Cult	
1969	Carman	120	126	126	ns
	Sanford	42	45	30	ns
1970	Portage	59	59	61	ns
	Sanford	58	65	59	ns
1971	Carman	72	73	79	ns
	Portage	75	71	70	ns
	Sanford	76	83	79	ns

Table 4.51 Fertile tillers of wheat and barley (tillers/ plant) under zero and conventional tillage at Portage, 1969 [a].

Crop	Treatment			LSD (.05)
	ZT 1	ZT 2	Cult	
Wheat	1.47	1.61	1.49	ns
Barley	1.13	1.18	0.96	ns

a Values are fertile tillers per plant based on four samples (1.5 m of row) per plot and six plots per treatment.

Table 4.52 Kernels per head for wheat and barley under zero and conventional tillage, 1971.

Crop	Location	Kernels/Head [a]		LSD (.05)
		ZT 1	Cult	
Wheat	Carman	27.5	28.8	ns
	Portage	23.7	25.1	ns
	Sanford	23.2	22.8	ns
Barley	Carman	38.4*	43.8	4.6
	Portage	36.4*	41.7	3.9
	Sanford	37.8	37.1	ns

a Based on an average of 50 heads per plot and six plots per treatment.

* Different compared to the cultivated treatment.

the number of kernels per head did not differ significantly. Presumably, small differences in these factors offset the differences in tillering.

Barley at Carman yielded lower under zero tillage than under conventional tillage due to a decrease in the number of kernels per head under zero tillage. Tillering and kernel weight did not differ between treatments. At Portage, the yield of barley did not differ between treatments but the kernel weight and the number of kernels per head were reduced under zero tillage, while tillering tended to be increased in the absence of tillage.

With rape and flax only seed weight and yield were determined. A change in seed yield not resulting from a change in kernel weight must have been due to a change in the number of seeds produced per unit area, and a change in kernel weight not accompanied by a corresponding change in seed yield must have been associated with a change in the number of seeds produced. With flax, increased seed yields which were observed under zero tillage at Sanford (1970 and 1971) and at Portage (1971) were the result of increased seed weight in only one instance (Sanford 1971). Therefore, other two differences were due to changes in the number of seeds produced. With rape at Carman in 1971 seed weight was increased under zero tillage but yield was not increased. The number of seeds produced under zero tillage must have been less than the number produced under cultivation. The increased seed yield of rape at Sanford in 1970 was due to an increase in the number of seeds produced since the seed weight did not differ between treatments.

The results indicated that all three yield components of cereals could be altered by the tillage treatment. With flax and rape, both seed weight and the number of seeds produced could be influenced by the tillage treatment, but the number of seeds produced was more readily effected. There was no consistent influence of zero tillage on any one of the yield components.

H. Soil fertility and nitrogen response

a) soil fertility

Soil samples were obtained from Portage on July 29, 1969, from all three locations in July 1970, and from Carman on May 10, 1972. The validity of the data was questionable due to the high coefficient of variation. A summary of all results are presented in Appendix E-1 to E-4.

b) nitrogen response

Because of the indication of a nitrogen deficiency under zero tillage from 1971 barley trials, nitrogen response trials were conducted in 1972. Yield results for wheat, barley, and rape are indicated in Tables 4.53 to 4.57. Protein contents of wheat and barley are presented in Tables 4.58 to 4.61.

Trials with five replicates were conducted on a sandy clay loam site (Carman B) while trials with three replicates were laid down on the large scale site at Carman (Carman A).

Wheat on the Carman B site exhibited a yield interaction between tillage and N fertilizer (Table 4.53). At N fertilizer levels of 134, 202, and 269 kg/ha, zero tillage yielded higher than conventional tillage. At fertility levels of 0, 67, and 101 kg/ha, no yield differences existed between tillage treatments. At 34 kg N/ha, the cultivated treatment yielded higher than the zero tillage treatment (370 kg/ha).

Table 4.53 Nitrogen response of wheat (yield) under zero [a] and conventional tillage at Carman B, 1972.

Nitrogen Applied (kg/ha)	Yield (kg/ha)		LSD (.05)
	ZT 1	Cult	
0	2533	2863	ns
34	2930*	3300	362
67	3474	3468	ns
101	3588	3347	ns
134	3656*	3259	362
202	3965*	3219	362
269	3730*	3273	362
LSD (.05) within treatment	228	228	

Interaction of tillage x N fertilizer significant at 1% level.

a Zero tillage plots under first year of zero tillage management.

* Different compared to the cultivated treatment.

Barley response trials at Carman B indicated lower yields under zero tillage than under cultivation when no nitrogen was applied (Table 4.54). At 34 kg/ha nitrogen, yield under cultivation was not significantly higher from yield under zero tillage. No yield differences existed at higher rates of nitrogen application. Tillage x nitrogen fertilizer interaction was not significant in this barley trial.

With wheat on the Carman B site (Table 4.55) the differences between the two tillage treatments, and the interaction, were not significant. At 202 and 269 kg/ha nitrogen, wheat under zero tillage tended to outyield wheat under conventional tillage.

Yield of barley and rape at Carman A followed a pattern similar to yield of wheat at Carman B, but tillage treatment differences and interaction were not significant (Tables 4.56 and 4.57).

Protein content of wheat exhibited an interaction between tillage treatment and nitrogen fertilizer at Carman B (Table 4.58). At 67 kg/ha nitrogen, protein content of wheat under cultivation was higher than protein content of wheat under zero tillage at the same fertility level. Differences at other nitrogen levels were not significant but at lower N levels, wheat under zero tillage tended to exhibit a lower protein content, while at higher N levels the reverse situation occurred.

Unless nitrogen availability to the plant varies,

Table 4.54 Nitrogen response of barley (yield) under zero[a] and conventional tillage at Carman B, 1972.

Nitrogen Applied (kg/ha)	Yield (kg/ha)		LSD (.05)
	ZT 1	Cult	
0	3599*	4664	672
34	4352	4869	ns
67	5337	5482	ns
101	5385	5493	ns
134	5482	5541	ns
202	5337	5477	ns
269	5229	5525	ns
LSD (.05) within treatment	488	488	

Interaction of tillage x N fertilizer not significant at 5% level.

a Zero tillage plots under first year of zero tillage management.

* Different compared to the cultivated treatment.

Table 4.55 Nitrogen response of wheat [a] (yield) under zero [b] and conventional tillage at Carman A, 1972.

Nitrogen Applied (kg/ha)	Yield (kg/ha) ZT 1	Yield (kg/ha) Cult	LSD (.05)
0	2063	2144	ns
34	2386	2547	ns
67	3111	2802	ns
101	2843	3044	ns
134	2775	2883	ns
202	3535	3017	ns
269	3488	3098	ns
LSD (.05) within treatment	373	373	

Interaction of tillage x N fertilizer not significant at 5% level.

a Wheat grown on plots at Carman which had grown rape in 1971.

b Zero tillage plots under fourth year of zero tillage management.

Table 4.56 Nitrogen response of barley [a] (yield) under zero [b] and conventional tillage at Carman A, 1972.

Nitrogen Applied (kg/ha)	Yield (kg/ha) ZT 1	Yield (kg/ha) Cult	LSD (.05)
0	3411	4229	ns
34	4202	4137	ns
67	4638	4503	ns
101	4643	4148	ns
134	4347	4110	ns
202	4535	4433	ns
269	4417	3884	ns
LSD (.05) within treatment	425	425	

Interaction of tillage x N fertilizer not significant at 5% level.

a Barley grown on plots at Carman which had grown flax in 1971.

b Zero tillage plots under fourth year of zero tillage management.

Table 4.57 Nitrogen response of rape [a] (yield) under zero [b] and conventional tillage at Carman A, 1972.

Nitrogen Applied (kg/ha)	Yield (kg/ha) ZT 1	Yield (kg/ha) Cult	LSD (.05)
0	694	554	ns
34	801	1047	ns
67	1389	1294	ns
101	1579	1406	ns
134	1758	1596	ns
202	1932	1719	ns
269	2195	1893	ns
LSD (.05) within treatment	175	175	

Interaction of tillage x N fertilizer not significant at 5% level.

a Rape grown on plots at Carman which had grown barley in 1971.

b Zero tillage plots under fourth year of zero tillage management.

Table 4.58 Nitrogen response of wheat (protein) under zero [a] and conventional tillage at Carman B, 1972.

Nitrogen Applied (kg/ha)	Protein Content (N x 5.7, 14% moisture)		LSD (.05)
	ZT 1	Cult	
0	11.3	11.9	ns
34	12.4	13.0	ns
67	12.5*	13.9	0.7
101	14.0	14.4	ns
134	14.7	14.5	ns
202	14.9	14.3	ns
269	15.0	14.5	ns
LSD (.05) within treatment	0.5	0.5	

Interaction of tillage x N fertilizer significant at 1% level.

a Zero tillage plots under first year of zero tillage management.

* Different compared to the cultivated treatment.

yield increases result in decreased protein content, and vice-versa. The increased yield and increased protein at high fertilizer levels indicate that more nitrogen was made available under zero tillage, or available nitrogen was used more efficiently by the zero tillage crop. Response to low fertilizer levels indicated that more nitrogen was not made available under zero tillage conditions. The interaction between tillage and nitrogen fertilizer was significant for the protein content of wheat in this trial.

The protein content of barley at Carman B did not differ between tillage treatments and an interaction was not evident (Table 4.59).

The protein content of wheat at Carman A did not show an interaction between tillage and nitrogen fertilizer (Table 4.60). Protein content at 34 and 67 kg/ha nitrogen was higher under cultivation than under zero tillage. Barley protein content data showed an interaction between tillage and fertilizer at this site (Table 4.61). At 0 and 34 kg/ha nitrogen, protein content under zero tillage was lower than for the cultivated treatment.

With wheat, the location (Carman B) which showed the yield interaction of tillage and fertilizer (Table 4.53) also showed a protein interaction (Table 4.58). When no yield differences were found (Carman A) (Table 4.55), no protein interaction was apparent (Table 4.60). However, protein content was lower under zero tillage at 34 and 67 kg/ha than under cultivation.

Table 4.59 Nitrogen response of barley (protein) under zero [a] and conventional tillage at Carman B, 1972.

Nitrogen Applied (kg/ha)	Protein Content (N x 6.25, 14% moisture)		LSD (.05)
	ZT 1	Cult	
0	10.5	10.8	ns
34	10.6	10.9	ns
67	11.1	11.7	ns
101	11.8	12.5	ns
134	12.6	13.0	ns
202	13.0	13.0	ns
269	12.9	12.8	ns
LSD (.05) within treatment	0.5	0.5	

Interaction of tillage x N fertilizer not significant at 5% level.

a Zero tillage plots under first year of zero tillage management.

Table 4.60 Nitrogen response of wheat [a] (protein) under zero [b] and conventional tillage at Carman A, 1972.

Nitrogen Applied (kg/ha)	Protein Content (N x 5.7, 14% moisture) ZT 1	Cult	LSD (.05)
0	11.1	11.6	ns
34	11.1*	12.4	1.1
67	11.6*	13.1	1.1
101	12.9	13.7	ns
134	13.4	13.8	ns
202	13.7	14.1	ns
269	13.9	14.1	ns
LSD (.05) within treatment	0.8	0.8	

Interaction of tillage x N fertilizer not significant at the 5% level.

a Wheat grown on plots at Carman which had grown rape in 1971.

b Zero tillage plots under fourth year of zero tillage management.

* Different compared to the cultivated treatment.

Table 4.61 Nitrogen response of barley [a] (protein) under zero [b] and conventional tillage at Carman A, 1972.

Nitrogen Applied (kg/ha)	Protein Content (N x 6.25, 14% moisture) ZT 1	Cult	LSD (.05)
0	10.3*	12.1	1.2
34	10.3*	11.7	1.2
67	11.5	12.1	ns
101	12.1	12.9	ns
134	12.8	13.0	ns
202	13.0	13.0	ns
269	13.5	13.3	ns
LSD (.05) within treatment	0.9	0.9	

Interaction of tillage x N fertilizer significant at the 1% level.

a Barley grown on plots at Carman which had grown flax in 1971.

b Zero tillage plots under fourth year of zero tillage management.

* Different compared to the cultivated treatment.

With barley, no yield interactions were observed (Tables 4.54 and 4.56). Only one yield difference was observed (Table 4.54) when yield under zero tillage was 1065 kg/ha less than the yield under cultivation when no nitrogen was applied. Barley at one location (Carman A) exhibited a protein content interaction (Table 4.61). At the two lowest rates of nitrogen, 0 and 34 kg/ha, protein content was lower under zero tillage than under cultivation. At high rates of nitrogen, protein content did not differ between treatments, as wheat did when an interaction was observed.

The yield and protein content at 0 kg N/ha indicated that less nitrogen was available on the zero tillage than on the conventional tillage plots. This fact was supported by results of Molberg and Hay (1968) who found that less nitrogen was available when the soil was not disturbed early in the season, than when an early tillage operation was carried out. Molberg and Hay were studying chemical summerfallow but the same results should occur under a cropped system. If less nitrogen was available at the time of seeding, the yield would be expected to decrease. As increasing amounts of fertilizer were added, the difference in available nitrogen would be expected to have a smaller effect. The yield results of the nitrogen response trials indicated that as the amount of fertilizer was increased from 0 to 67 kg N/ha, the yield difference between zero and conventional tillage decreased. At higher rates of N fertilizer, the zero tillage crops used the nitrogen fertilizer more efficiently than crops grown with conventional tillage and higher yields were produced under zero tillage. The superior establishment observed under zero tillage conditions, relative to cultivation, would be expected to result in a more efficient crop stand, provided that some factor did not become limiting.

A factor which would have increased the difference in available nitrogen between the zero and conventional tillage treatments was the increased dry matter produced during the early growing season under zero tillage.

The expected protein content of Neepawa wheat can be calculated from the soil nitrate content at the time of seeding and nitrogen fertilizer applied, according to equations derived by Alkier et al. (1972) and Racz (personal communication). These equations are presented in Appendix C-3. A comparison of yield of wheat and protein content of wheat in these trials, wheat yield and protein content data of Alkier et al. (1972), and calculated protein values, are presented in Appendix C-4.

Protein contents followed the values predicted by the quadratic equation (Appendix C-3b) more closely than the values predicted by the cubic equation (Appendix C-3a). Observed protein values under zero tillage ranged from 11.4 to 15.1% protein. Calculated values ranged from 11.3 to 16.1% protein. Wheat under cultivation had a narrower protein content range (12.0 to 14.6) than did wheat under zero tillage.

Alkier *et al.* (1972) found a decrease in protein content from 12.1% to 11.7% when 34 kg/ha of nitrogen was applied. This decrease was not observed under either zero or conventional tillage. Alkier *et al.* (1972) showed a 46% yield increase when 34 kg N/ha was applied, while zero tillage trials showed a 16% yield increase. The large yield response (640 kg/ha) which was obtained by Alkier *et al.* (1972) would be expected to result in decreased protein contents. In general, Alkier *et al.* (1972) obtained low grain yields (1400 to 2710 kg/ha).

The absence of the decrease in protein with the application of nitrogen may have been due to climatic differences (1970 and 1971 average versus 1972 data) or due to the higher yield produced with no fertilizer (1400 versus 2863 kg/ha).

The data indicated that the protein content of wheat grown under zero tillage responded as predicted by the equation derived by Racz (Appendix C-3b). Wheat from the other location responded in a similar manner (Table 4.60). Tillage is a factor which should be considered in predicting wheat protein content.

I. Herbicide evaluation experiments

a) field evaluations

i/ Evaluation of several herbicides for chemical seedbed preparation, 1972.

Dinoseb at 4.48 and 8.97 kg/ha resulted in very good weed control (Table 4.62). Initial weed kill was rapid (within 24 hours) and complete. Dinoseb appeared to result in residual control of some weeds, including green foxtail, wild oats, and broad-leaved weeds.

Bromoxynil plus MCPA and paraquat gave satisfactory control of all weeds. Bromoxynil plus MCPA controlled the broad-leaved weeds but the grassy weeds became more serious, as indicated by the July 6 rating (Table 4.62). The other treatments were not satisfactory.

The importance of grass control was indicated in this experiment. If broad-leaved weeds were removed, the remaining grassy weeds had a competitive advantage over the emerging crop.

ii/ Evaluation of low rates of paraquat and paraquat-diquat mixtures for zero tillage seedbed preparation, 1972.

When paraquat was applied in 243 l/ha spray volume in the morning, 0.56 kg/ha was the lowest acceptable rate (Table 4.63). Paraquat at 1.12 kg/ha was more effective than 0.56 kg/ha, and was as good as 2.24 kg/ha and the combination of paraquat plus diquat (0.84 + 0.28 kg/ha). When diquat was used to replace some paraquat, treatments 10-12, the control was less than with the equivalent rate of paraquat.

Paraquat at 0.28 kg/ha was more effective when applied at dusk than when applied in the early morning (Table 4.63). At lower rates no differences were apparent.

Table 4.62 Evaluation of several herbicides for chemical seedbed preparation, 1972.

Treatment			Control Rating[a]	
No.	Herbicide	Rate (kg/ha)	May 31	July 6
1.	check	———	1	1
2.	paraquat + diquat	0.84 + 0.28	7	8
3.	nitrofen	1.34	3	4
4.	2,4-D amine	0.84	5	4
5.	dicamba + 2,4-D + mecoprop	0.56	5	5
6.	bromoxynil + MCPA	0.56	7	5
7.	bromoxynil + MCPA + paraquat	0.56 + 0.28	7	7
8.	bromoxynil + MCPA + paraquat	0.56 + 0.14	7	6
9.	amitrol-T	4.48	5	6
10.	dinoseb	4.48	9	7
11.	dinoseb	8.97	9	8

a Rated on a scale of 1-9, with 1 indicating no control. No statistical analysis carried out on ratings.

Table 4.63 Evaluation of low rates of paraquat and paraquat-diquat mixtures for zero tillage seedbed preparation, 1972.

Treatment				Control Rating [a]	
No.	Herbicide	Rate (kg/ha)	Time of Application	May 31	July 6
1.	check	———	——	1	1
2.	paraquat + diquat	0.84 + 0.28	AM	8	8
3.	paraquat	2.24	AM	8	8
4.	paraquat	1.12	AM	8	8
5.	paraquat	0.56	AM	6	6
6.	paraquat	0.42	AM	5	4
7.	paraquat	0.28	AM	4	3
8.	paraquat	0.14	AM	2	3
9.	paraquat	0.07	AM	1	1
10.	paraquat + diquat	0.28 + 0.28	AM	5	5
11.	paraquat + diquat	0.28 + 0.14	AM	4	4
12.	paraquat + diquat	0.14 + 0.14	AM	3	3
13.	paraquat	0.28	PM	6	5
14.	paraquat	0.14	PM	2	3
15.	paraquat	0.07	PM	1	3

a Rated on a scale of 1-9, with 1 indicating no control. No statistical analysis carried out on ratings.

Very little control resulted under either condition, at rates of 0.14 and 0.07 kg/ha.

iii/ Evaluation of the effect of spray volume on efficacy of paraquat, 1972.

The effect of spray volume on the efficacy of paraquat was evaluated (Table 4.64). At the rates of paraquat used (0.28 and 0.56 kg/ha), and for the type of weed canopy, decreasing spray volume from 243 to 69 l/ha increased weed control. Satisfactory control was obtained with 0.28 kg/ha paraquat. Results indicated that additional surfactant may be required for low rates of paraquat.

iv/ Evaluation of glyphosate (MON 2139) for zero tillage weed control, 1972.

Glyphosate at rates from 0.28 to 1.12 kg/ha resulted in satisfactory weed control (Table 4.65). No differences were evident between rates of 0.56 to 1.12 kg/ha. Glyphosate at 0.14 kg/ha resulted in some grass control but was poor on broad-leaved weeds. Glyphosate at 0.28 kg/ha was sufficient for grass control. Paraquat at 0.56 kg/ha was almost as effective as paraquat plus diquat at 0.84 + 0.28 kg/ha. The split application of glyphosate and paraquat was no better than the 0.14 kg/ha rate of glyphosate.

b) greenhouse evaluations

i/ The effect of spray volume and surfactant on efficacy of paraquat.

Table 4.64 Evaluation of effect of spray volume on efficacy of paraquat, 1972.

Treatment			Control Rating [a]	
No.	Rate of Paraquat (kg/ha)	Spray Volume (l/ha)	May 31	July 6
1.	check	—	1	1
2.	0.56	69	8	8
3.	0.56	138	8	7
4.	0.56	183	7	6
5.	0.56	243	7	5
6.	0.28	69	7	7
7.	0.28	138	5	5
8.	0.28	183	4	5
9.	0.28	243	4	4

a Rated on a scale of 1-9, with 1 indicating no control. No statistical analysis carried out on ratings.

Table 4.65 Evaluation of MON 2139 for zero tillage weed control, 1972.

Treatment			Control Rating [a]	
No.	Herbicide	Rate (kg/ha)	May 31	July 6
1.	check	———	1	1
2.	MON 2139	0.07	1	3
3.	MON 2139	0.14	3	4
4.	MON 2139	0.28	6	7
5.	MON 2139	0.56	7	8
6.	MON 2139	0.84	8	8
7.	MON 2139	1.12	8	8
8.	paraquat + diquat	0.84 + 0.28	8	8
9.	paraquat	0.56	7	7
10.	paraquat	0.28	4	5
11.	paraquat	0.14	2	3
12.	MON 2139 and paraquat	0.14 + 0.14	3	4

a Rated on a scale of 1-9, with 1 indicating no control. No statistical analysis carried out on ratings.

The effect of spray volume and surfactant (Agral 90) on efficacy of paraquat was tested in the greenhouse (Table 4.66). Treatments 6 to 9 indicated that the volume effect observed in the field was present under conditions of this trial. The addition of 0.1% Agral 90 did not prevent the volume effect (Treatments 2 to 5). Also, the addition of Agral 90 to paraquat (331 l/ha spray volume) did not improve the control over that obtained at the same rate and spray volume with no additional surfactant. These trials indicated that paraquat, when applied at low rates was more effective when the spray volume was reduced to 57 l/ha. The addition of surfactant, along with an increase in spray volume did not offset the decreased control due to increased spray volume. Possibly, the increase in concentration of the spray solution increased the efficacy.

The results of this experiment are in agreement with the results of M^{c}Kinlay (1973) who found that paraquat at 0.5 oz/A was more toxic to sunflower seedlings when applied in 0.5 gpa than in 2 gpa.

ii/ Residual effect of dinoseb on emergence and growth of green foxtail, wild oats, wheat, barley and tame oats.

The number of green foxtail seedlings emerging was reduced by 8.96 and 17.92 kg/ha dinoseb (Table 4.67). All rates resulted in a reduction in the weight of foliage per pot. Dinoseb at 17.92 kg/ha resulted in a 98% reduction

Table 4.66 The effect of spray volume and surfactant on efficacy of paraquat applied at 0.14 kg/ha in the greenhouse, 1972.

Treatment				
No.	Formulation	Spray Volume (l/ha)	% Agral 90 Added	Control Rating[a]
1.	check	—	—	1
2.	aerial paraquat[b]	57	0.1	7
3.	aerial paraquat	128	0.1	6
4.	aerial paraquat	171	0.1	5
5.	aerial paraquat	331	0.1	4
6.	paraquat[c]	57	—	7
7.	paraquat	128	—	6
8.	paraquat	171	—	5
9.	paraquat	331	—	5
10.	paraquat	331	0.1	4

a Rated on a scale of 1-9, with 1 indicating no control. No statistical analysis carried out on ratings.

b Formulation of paraquat containing no surfactant.

c Formulation of paraquat containing surfactant.

in dry weight, relative to the unsprayed check.

Wild oats were not as sensitive to dinoseb as was green foxtail. Only the 17.92 kg/ha rate reduced the number of emerging seedlings (Table 4.68). Dry weights were not significantly different. During early stages of growth (emergence to 2 leaf stage) the wild oats treated with 8.96 and 17.92 kg/ha dinoseb exhibited some injury symptoms (stunting, slight chlorosis, loss of turgor), but they soon grew out and were not noticeably different from the unsprayed check.

Wheat and barley showed tolerance to dinoseb at all rates (Tables 4.69 and 4.70). Tame oats exhibited tolerance to 8.96 kg/ha dinoseb (Table 4.71). Oats were not tested at higher rates of dinoseb.

iii/ Green foxtail emergence after pre emergence herbicide applications.

The effect of paraquat, 2,4-D amine and 2,4-D ester on green foxtail germination is indicated in Table 4.72. All treatments reduced germination of green foxtail when seeds were on the surface. Germination was lower with surface seeding than with seeding at a one centimeter depth (8.6 versus 14.4 plants/pot). The 2,4-D treatments had no effect on germination when the seed was protected by 1 cm of soil.

Possibly the ZT 2 treatment in 1969 and 1970 (paraquat plus 2,4-D ester) reduced the germination of green foxtail on the soil surface and resulted in a reduced green foxtail

Table 4.67 Residual effect of dinoseb on emergence and growth of green foxtail in the greenhouse, 1972.

Treatment No.	Treatment Rate (kg/ha)	Emergence (plants/pot)	Dry Plant Weight (g/pot)
1.	0	33	1.20
2.	4.48	29	0.92*
3.	8.96	12*	0.36*
4.	17.92	5*	0.02*
	LSD (.05)	9	0.27

* Different compared to the untreated check.

Table 4.68 Residual effect of dinoseb on emergence and growth of wild oats in the greenhouse, 1972.

Treatment No.	Treatment Rate (kg/ha)	Emergence (plants/pot)	Dry Plant Weight (g/pot)
1.	0	14	0.27
2.	4.48	13	0.26
3.	8.96	13	0.25
4.	17.92	11*	0.13
	LSD (.05)	2	ns

* Different compared to the untreated check.

Table 4.69 Residual effect of dinoseb on emergence and growth of wheat in the greenhouse, 1972.

Treatment		Emergence	Dry Plant Weight
No.	Rate (kg/ha)	(plants/pot)	(g/pot)
1.	0	6	0.79
2.	4.48	6	0.90
3.	8.96	5	0.81
4.	17.92	6	0.73
	LSD (.05)	ns	ns

Table 4.70 Residual effect of dinoseb on emergence and growth of barley in the greenhouse, 1972.

Treatment		Emergence	Dry Plant Weight
No.	Rate (kg/ha)	(plants/pot)	(g/pot)
1.	0	5	4.55
2.	4.48	6	4.59
3.	8.96	6	4.61
4.	17.92	6	4.48
	LSD (.05)	ns	ns

Table 4.71 Residual effect of dinoseb (8.96 kg/ha) on emergence and growth of tame oats (cv. Harmon) in the greenhouse, 1972.

Treatment	Plants/Pot	Dry Wt./Pot (g)
Check	5	1.04
Dinoseb	5	0.92
LSD (.05)	ns	ns

Table 4.72 Green foxtail emergence after pre emergence herbicide applications.

Planting Depth (cm)	Herbicide and Rate (kg/ha)	Seedlings Emerging From 20 Seeds	% of Check
0	check	8.6	100
0	2,4-D amine 1.12	0.3*	3
0	2,4-D ester 1.12	0.2*	2
0	paraquat 1.12	2.1*	24
1	check	14.4	100
1	2,4-D amine 1.12	13.7	95
1	2,4-D ester 1.12	13.3	92
	LSD (.05)	2.7	

* Different from the check at the same planting depth.

population under this treatment, as compared to ZT 1. Paraquat may have reduced the germination of green foxtail on the soil surface of zero tillage plots.

c) discussion of herbicide evaluation experiments

The trials with paraquat indicated that the rate could be reduced from 1.12 kg/ha, particularily if the spray volume was reduced to 57 to 69 l/ha. On the weed canopy which was present in these trials, the replacement of some paraquat by diquat reduced the weed control. Late evening applications of paraquat were superior to early morning applications. The results in Table 4.72, and the results obtained by Appleby and Brenchley, regarding the effect of paraquat on germination of seeds of grass species indicate a possible means by which weed seedling emergence may be reduced under zero tillage.

The results indicated that low rates of paraquat should be applied in approximately 60 l/ha spray volume, and application should be made in the evening. At low rates of herbicide, diquat should not be mixed with paraquat.

Bromoxynil plus MCPA and paraquat (0.56 + 0.28 kg/ha) gave satisfactory weed control in these trials. Weed control was similar to that obtained in large scale trials in 1971 (ZT 2). In a weed stand with a high proportion of broad-leaved weeds, the bromoxynil plus MCPA and paraquat (0.56 + 0.28 kg/ha) should be as effective as paraquat plus diquat (0.84 + 0.28 kg/ha). In a grassy weed stand, the paraquat-diquat mixture should be more effective.

Dinoseb applications resulted in very good weed control. Residual control of broad-leaved weeds, green foxtail and wild oats was observed. In the greenhouse, the residual effect on wild oats was slight. Crop competition was probably an important factor in the field trials. Wheat was tolerant to pre emergence dinoseb applications in both the field and the greenhouse. Barley and tame oats were tolerant to pre emergence applications of dinoseb in the greenhouse.

Glyphosate gave good weed control at low rates of application. The perennial weed control which can be obtained at high rates of application, and the good annual weed control obtained at low rates indicate that glyphosate would be a satisfactory herbicide for chemical seedbed preparation.

The herbicide evaluation experiments indicated that several herbicide treatments could produce satisfactory chemical seedbed weed control. Selective residual control with dinoseb was also shown.

J. General discussion and summary

This study clearly indicated that annual weed populations were reduced by three years of zero tillage management. The species which were reduced in number were green foxtail, wild oats, green smartweed, and wild buckwheat. Perennial weeds such as quack grass and Canada thistle were problems under zero tillage.

Possible reasons for the reduction of the annual weed populations are:

i/ Weed seeds may not have been brought up to the soil surface where conditions were suitable for germination.

ii/ Weed seed dormancy may have increased due to compaction in the surface soil layer.

iii/ Herbicides, in particular paraquat and 2,4-D, may have reduced the viability of weed seeds on the soil surface.

iv/ Crop competition from the vigorous zero tillage stand may have reduced the weed population.

Several herbicide treatments gave good weed control in these trials. These are listed in the conclusions.

The weed seed populations were not influenced by two years of zero tillage. Possibly a longer time period would reduce the weed seed population under zero tillage. A longer time period should result in a greater reduction of the annual weed population.

Crop development was satisfactory under zero tillage conditions. More plants emerged and grew faster under zero tillage. Root development was similar under both zero and conventional tillage. The crops matured earlier under zero tillage and generally produced yields equal to yields on conventional tillage plots. Bushel weight, seed weight, protein content (wheat and barley) and oil content (rape and flax) were similar under both zero and conventional tillage.

Fertility trials indicated that zero tillage plots produced poorer crops than conventionally tilled plots when the fertility level was low, but when adequate fertilizer was applied, zero tillage crops outyielded conventional tillage crops. Nitrogen fertilizer was used more efficiently under zero tillage than under conventional tillage. The results indicated that zero tillage would fit into a target yield program and might result in higher grain protein contents than could be obtained under conventional tillage.

In conclusion, the trials indicated that crops could be produced without tillage if the plots were properly managed. Figure 4.4 shows stands of wheat and barley grown under zero tillage management.

Figure 4.4 Wheat (top) and barley (bottom) grown under zero tillage at Portage, 1970.

CONCLUSIONS

1. Crops could be produced under zero tillage conditions provided that proper management practices were carried out.
2. The annual weed populations could be reduced under zero tillage but perennial weeds presented problems.
3. More crop seedlings emerged under zero tillage and these seedlings grew more rapidly than seedlings grown under conventional tillage.
4. Root development was not restricted under zero tillage conditions.
5. Zero tillage required the use of adequate fertilizer if yields were to be equal to yields obtained under conventional tillage, but high rates of fertilizer were used more efficiently in the absence of tillage.
6. Paraquat, when applied at low rates (0.28 and 0.56 kg/ha) was more effective when the spray volume was reduced.
7. Dinoseb at 4.48 and 8.97 kg/ha resulted in good weed control and gave residual control of green foxtail, wild oats and broad-leaved weeds.
8. Paraquat, 2,4-D amine, and 2,4-D ester reduced the germination of green foxtail seeds which were on the soil surface.
9. Herbicide treatments which were effective for zero tillage seedbed weed control were:

    i/ paraquat plus diquat at 0.84 plus 0.28 kg/ha.

ii/ paraquat plus 2,4-D ester at 0.84 plus 1.12 kg/ha.

iii/ bromoxynil and MCPA plus paraquat at 0.56 plus 0.28 kg/ha.

iv/ paraquat at 0.28 kg/ha applied in 69 l/ha spray volume.

v/ glyphosate at 0.56 kg/ha.

vi/ dinoseb at 4.48 and 8.97 kg/ha.

RECOMMENDATIONS

1. Field evaluations of zero tillage should be carried out to ensure that the benefits of zero tillage can be realized on a commercial scale operation.
2. Zero tillage should be evaluated during an abnormally dry season to indicate the value of conserving moisture in the seedbed.
3. Seeding dates and harvesting dates under zero tillage should be evaluated.
4. Stale seedbed crop production should be compared to zero tillage production. Stale seedbed production could serve as an intermediate step between zero and conventional tillage.
5. Zero tillage should be evaluated in conjunction with chemical summerfallow in areas where summerfallow is considered to be necessary in the cropping rotation.
6. Other crops should be evaluated for production under zero tillage. Crops which are slow to emerge and which require a relatively moist seedbed should respond favourably to zero tillage.
7. The effect of zero tillage on wild oat populations should be considered. Wild oats are not adapted to zero tillage conditions. A combination of zero tillage and chemical control could reduce the wild oat problem.
8. The search for a herbicide, or a mixture more suited to zero tillage should continue.

9. The residual properties of dinoseb should be further evaluated to confirm crop tolerance and weed control. The green foxtail and wild oat control in cereal crops should be considered for further testing.
10. The slight difference in tolerance of wild oats and tame oats to dinoseb should be evaluated in field trials.
11. The triple disc drill system should be modified. A larger cutting disc and more convenient depth control would be necessary for a commercial drill.
12. The physical properties of soils under zero tillage should be evaluated early in the growing season when the greatest differences between tillage treatments would be expected.
13. The costs of zero tillage should be compared to the costs of conventional tillage in order that a cost limit for the herbicide treatment would be known.

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APPENDICES

Appendix A-la. Meteorological data [a] (temperature)

Location	Month	Mean Temperature (°F)								
		1969			1970			1971		
		Max.	Min.	Daily	Max.	Min.	Daily	Max.	Min.	Daily
Graysville [b]	May	na	na	na	60.0	37.1	48.6	66.3	36.6	51.5
	June	67.8	41.4	54.6	79.5	51.9	65.7	76.0	51.6	63.8
	July	76.5	53.6	65.1	na	na	na	na	na	na
	Aug.	82.8	55.5	69.3	80.3	49.0	64.7	na	na	na
	Sept.	67.8	41.4	54.6	66.9	42.0	54.5	67.3	42.7	55.0
Portage [c]	May	62.3	38.7	50.5	59.1	39.2	49.2	65.1	38.1	51.6
	June	65.8	43.5	54.7	78.1	55.6	66.9	74.3	53.2	63.8
	July	75.6	54.5	65.1	79.5	58.1	68.8	72.7	52.7	62.7
	Aug.	81.4	57.6	69.5	78.6	53.6	66.1	78.7	53.5	66.1
	Sept.	65.9	44.1	55.0	66.5	43.8	55.2	66.5	45.3	55.9
Starbuck [d]	May	64.7	39.6	52.2	59.5	39.7	49.6	66.3	37.3	51.8
	June	66.2	44.8	55.5	79.7	54.9	67.3	75.3	53.4	64.4
	July	75.5	53.8	64.7	81.8	58.2	70.0	73.2	51.9	62.6
	Aug.	81.9	58.7	70.3	79.2	53.1	66.2	78.8	53.8	66.3
	Sept.	66.5	46.3	56.4	66.9	45.1	56.0	68.1	45.1	56.6

a Extracted from Department of Transport Meteorological Observations in Canada.
b Closest weather station to the Carman plot site.
c Canadian Forces Base.
d Closest weather station to the Sanford plot site.
na Not available.

Appendix A-lb. Meteorological data [a] (precipitation in inches).

Time Period	Location		
	Graysville [b]	Portage [c]	Starbuck [d]
Oct. 68-April 69	7.56	8.06	7.07
May 69	2.01 [e]	2.15	2.55
June 69	4.10	3.58	4.25
July 69	3.77	4.15	3.96
Aug. 69	2.21	4.44	2.87
Sept. 69	1.53	1.29	2.35
May 69-Sept. 69	13.62	15.61	15.98
Oct. 68-Sept. 69	21.18	23.67	23.05
Oct. 69-April 70	9.25	8.90	8.77
May 70	2.75	2.44	2.41
June 70	2.26	2.06	2.36
July 70	2.72 [e]	2.56	2.92
Aug. 70	1.75	2.23	2.09
Sept. 70	2.21	2.41	3.07
May 70-Sept. 70	11.69	11.70	12.85
Oct. 69-Sept. 70	20.94	20.60	21.62
Oct. 70-April 71	8.98	8.23	9.13
May 71	2.50	1.19	2.03
June 71	4.84	4.90	5.83
July 71	2.95 [e]	4.28	5.07
Aug. 71	1.21 [e]	0.47	0.79
Sept. 71	3.28	1.95	1.38
May 71-Sept. 71	14.78	12.79	15.30
Oct. 70-Sept. 71	23.76	21.02	24.43
Oct. 71-April 72	9.47	-	-
May 72	1.92 [e]	-	-
June 72	2.06 [e]	-	-
July 72	2.22	-	-
Aug. 72	2.28 [e]	-	-
May 72-Aug. 72	8.48	-	-
Oct. 71-Aug. 72	17.95	-	-

a Extracted from Department of Transport Meteorological Observations in Canada.
b Closest weather station to the Carman plot site.
c Canadian Forces Base.
d Closest weather station to the Sanford plot site.
e Data not available for Graysville station. Readings taken from Carman weather station.

Appendix A-2. Soil characteristics for large scale trials.

	Carman	Sanford	Portage
Texture			
Sand (%)	81	11	na
Silt (%)	12	28	na
Clay (%)	7	61	na
Specific gravity	2.50	2.47	na
Legal location	SW 6-5-28	NW 8-1E-7	SW 12-6-28
Reference	1	2	3

na not available

References

1. Soils Report No. 4. 1943. Report of Reconnaissance Soil Survey of South-Central Manitoba by J. H. Ellis and Wm. H. Shafer. pp. 88-89.

2. Soils Report No. 5. 1953. Report of Reconnaissance Soil Survey of Winnipeg and Morris Map Sheet Areas by W. A. Ehrlich, E. A. Poyser, L. E. Pratt, and J. H. Ellis. pp. 20-21.

3. Manitoba Soil Survey Report No. 17. 1972. Soils of the Portage la Prairie Area by W. Michalyna, R. E. Smith, and R. A. Milne. pp. 34-38, Map No. 16.

Appendix A-3. Nitrate nitrogen present in fertility trials at time of seeding, 1972.

Crop	Location	Treatment	NO_3-N (kg/ha to 61 cm)
Wheat	Carman B [a]	ZT and Cult	22.4
	Carman A [b]	ZT	28.9
		Cult	29.2
Barley	Carman B	ZT and Cult	22.4
	Carman A	ZT	38.1
		Cult	38.1
Rape	Carman A	ZT	28.9
		Cult	19.6

a Location at Carman where plots were in first year of zero tillage management.

b Location at Carman where plots were in fourth year of zero tillage management.

Appendix A-4a. Carman cropping history prior to initiation of trials.

Year	Tillage [a]	Crop	Seeding Date	Fertilizer (kg/ha)	Yield (kg/ha)
1968	P,C,H	wheat	June 18	11-48-0 @ 106	2500
1967	D,C,H	flax	June 8	34- 0-0 @ 56	1300
				23-23-0 @ 34	
1966	P,D,H	wheat	June 9	34- 0-0 @ 112	2100
				23-23-0 @ 84	
1965	P (fall), C,H	flax	May 28	34- 0-0 @ 56	800
				11-48-0 @ 34	
1964	C,D,H	wheat	May 26	34- 0-0 @ 56	2100
1963	D,C,H	wheat	May 18	23-23-0 @ 90	2000

a Tillage legend

C = cultivated

D = disced

H = harrowed

P = ploughed

Appendix A-4b. Portage cropping history prior to initiation of trials.

Year	Crop	Fertilizer (kg/ha)
1968	flax	N @ 56
1967	rape	11-48-0 @ 45 and N @ 56
1966	wheat	16-48-0 @ 56 and N @ 22
1965	wheat	16-48-0 @ 56 and N @ 22
1964	potatoes	16-48-0 @ 168
1963	flax	11-48-0 @ 45
1962	wheat	11-48-0 @ 45
1961	wheat	11-48-0 @ 45
1960	sugar beets	11-48-0 @ 90
1959	summerfallow	

Appendix B-1. Tillage operations.

Year	Location		
	Carman	Portage	Sanford
1969	Disced twice	Cultivated and harrowed	Cultivated and harrowed
1970	Disced and harrowed	Cultivated and harrowed	Cultivated and harrowed
1971	Disced and harrowed	Cultivated, disced and harrowed	Disced and harrowed

Appendix B-2. Seeding dates.

Location	Year		
	1969	1970	1971
Carman	May 29, 30	May 27, 28, 29	May 15, 16, 18
Portage	June 5	June 2	May 28, 29
Sanford	June 13, 16	June 5	May 13, 14

Appendix B-3. Crop varieties grown in zero tillage trials.

Year	Location	Crop			
		Wheat	Barley	Flax	Rape
1969	Carman	Manitou	Paragon	Noralta	Target
	Portage	Manitou	Conquest	Noralta	Target
	Sanford	Manitou	Paragon	Noralta	Target
1970	Carman	Manitou	Conquest	Noralta	Target
	Portage	Manitou	Conquest	Noralta	Target
	Sanford	Manitou	Conquest	Noralta	Target
1971	Carman	Manitou	Conquest	Noralta	Turret
	Portage	Manitou	Conquest	Noralta	Turret
	Sanford	Manitou	Conquest	Noralta	Turret

Appendix B-4. Fertilizer applied in zero tillage trials (kg/ha).

Year	Location	Crop							
		Wheat		Barley		Flax		Rape	
		N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5
1969	Carman	74	39	74	39	67	0	72	25
	Portage	67	34	67	34	67	0	67	34
	Sanford	69	13	69	13	67	0	67	0
1970	Carman	25	43	25	43	0	0	52	21
	Portage	27	34	27	34	0	0	25	25
	Sanford	22	28	22	28	57	0	62	21
1971	Carman	66	45	66	45	56	0	61	22
	Portage	73	28	76	39	67	0	90	22
	Sanford	67	28	34	34	67	0	78	0

Appendix B-5. Post emergent herbicides applied in large scale trials.

Year	Crop	Location	Herbicide	Rate (kg/ha)	Date of Application
1969	Wheat	Carman	bromoxynil + MCPA	0.56	July 7
		Portage	bromoxynil + MCPA	0.56	July 10
		Sanford	bromoxynil + MCPA	0.56	July 17
	Barley	Carman	TCA	1.12	July 3
			bromoxynil + MCPA	0.56	July 7
		Portage	none		
		Sanford	TCA	1.12	July 16
			bromoxynil + MCPA	0.56	July 17
	Flax	Carman	TCA	4.48	July 3
			bromoxynil + MCPA	0.56	July 7
		Portage	TCA	4.48	July 10
			bromoxynil + MCPA	0.56	July 10
		Sanford	TCA	4.48	July 16
			bromoxynil + MCPA	0.56	July 17
	Rape	Carman	TCA	4.48	July 3
		Portage	TCA	4.48	July 10
		Sanford	TCA	4.48	July 16
			nitrofen	1.34	July 17
1970	Wheat	Carman	barban	0.35	June 8
			dicamba + 2,4-D + mecoprop	0.56	June 17
		Portage	barban	0.35	June 13
			MCPA	0.70	b
		Sanford	MCPA	0.70	c
	Barley	Carman	barban	0.35	June 8
			dicamba + 2,4-D + mecoprop	0.42	June 17
		Portage	barban	0.35	June 13
			MCPA	0.70	b
		Sanford	MCPA	0.70	c

Appendix B-5. Continued...

Year	Crop	Location	Herbicide	Rate (kg/ha)	Date of Application
1970	Flax	Carman	barban	0.35	June 8
			MCPA	0.70	July 4
			TCA	4.48	a
		Portage	barban	0.35	June 13
			TCA	4.48	b
			MCPA	0.70	b
		Sanford	TCA	4.48	c
			MCPA	0.70	c
	Rape	Carman	barban	0.35	June 8
			nitrofen	1.34	June 24
			TCA	4.48	June 24
		Portage	barban	0.35	June 13
			TCA	4.48	b
			nitrofen	1.34	b
		Sanford	nitrofen	1.34	c
			TCA	4.48	c
1971	Wheat	Carman	barban	0.28	June 3
			MCPA	0.56	June 4
			dicamba + 2,4-D + mecoprop	0.56	June 14
		Portage	barban	0.42	June 14
			dicamba + 2,4-D + mecoprop	0.56	June 16
		Sanford	dicamba + 2,4-D + mecoprop	0.56	June 11
			MCPA	0.70	June 17
	Barley	Carman	barban	0.28	June 3
			TCA	1.40	June 4
			dicamba + 2,4-D + mecoprop	0.42	June 14
		Portage	barban	0.42	June 14
			MCPA	0.56	June 16
			TCA	1.40	June 16
		Sanford	TCA	2.24	June 11
			dicamba + 2,4-D + mecoprop	0.42	June 11
	Flax	Carman	barban	0.28	June 3
			dalapon	1.40	June 3
			MCPA	0.56	June 3
			bromoxynil + MCPA	0.56	June 14

Appendix B-5. Continued...

Year	Crop	Location	Herbicide	Rate (kg/ha)	Date of Application
1971	Flax	Portage	barban	0.42	June 14
			MCPA	0.35	June 16
		Sanford	dalapon	1.40	June 13
			bromoxynil + MCPA	0.56	June 13
	Rape [d]	Carman	barban	0.28	June 3
			TCA	4.48	June 3
			nitrofen	1.34	June 14
		Portage	barban	0.42	June 14
			TCA	4.48	June 16
			nitrofen	1.34	June 16
		Sanford	TCA	4.48	June 11
			nitrofen	1.34	June 13

a Applied after June 16.

b Applied after June 19.

c Applied after June 24.

d Rape at Carman and Sanford was spot treated with benazolin at 0.70 kg/ha for Canada thistle control.

Appendix B-6. Post emergent herbicides applied in fertility trials.

Crop	Location	Herbicide	Rate (kg/ha)	Date of Application
Wheat	Carman B [a]	bromoxynil + MCPA	0.56	June 12
	Carman A [b]	dicamba + 2,4-D + mecoprop	0.56	June 12
Barley	Carman B [a]	bromoxynil + MCPA	0.56	June 12
	Carman A [b]	dicamba + 2,4-D + mecoprop	0.42	June 12
Rape	Carman A	TCA	4.48	June 20
		benazolin	0.70	June 20

a Zero tillage plots under first year of zero tillage management.

b Zero tillage plots under fourth year of zero tillage management.

Appendix C-1. Number of seeds in 1.5 meters of crop row.

Crop	Seed/1.5 m		
	1969 [a]	1970 + 1971 [b]	Standard Deviation [c]
Wheat	56	65	2
Barley	76	89	4
Flax	168	196	14
Rape	73	85	20

a Calculated from 1970 + 1971 values.

b Determined for 1972 seeding operations, with similar seed and the same seeding rates as used in previous years.

c Calculated for 1970 and 1971 data.

Appendix C-2. Harvesting details for experimental samples from large scale trials.

Year	Location	Crop	Sample Size (meters)	Harvest Method
1969	Carman	all crops	2.4 x 106.6	swathed and combined with a commercial combine
	Sanford	all crops	2.4 x 106.6	swathed and combined with a commercial combine
	Portage	wheat, barley & flax	1.2 x 152.2	cut and stooked
		rape	5.4 x 30.5	swathed and combined with a commercial combine
1970	Sanford	wheat	1.2 x 106.6	cut and stooked
		barley, flax & rape	1.2 x 106.6	straight combined (Hege 125)
	Portage	wheat & barley	1.2 x 152.2	straight combined (Hege 125)
		flax	1.2 x 76.1	straight combined (Hege 125)
		rape	5.4 x 30.5	swathed and combined with a commercial combine
1971	Carman	wheat & flax	1.2 x 106.6	straight combined (Hege 125)
		barley	2.4 x 106.6	straight combined (Hege 125)
		rape	1.2 x 106.6	desicated and straight combined (Hege 125)
	Sanford	wheat, barley & flax	1.2 x 106.6	straight combined (Hege 125)
	Portage	wheat & barley	1.2 x 152.2	straight combined (Hege 125)
		flax	1.2 x 106.6	straight combined (Hege 125)
		rape	1.2 x 152.2	desicated and straight combined (Hege 125)

Appendix C-3a. Equation derived by Alkier *et al.* (1972) for calculation of percent protein.

$$\%P = 9.60 + 0.186x_1^2 + 0.0000124x_1^3 + 0.0232y + 0.0000662y^2 - 0.00000024y^3 - 0.000375x_1y + 0.00000160x_1^2y + 0.00000015x_1y^2$$
$(R^2 = 0.78^{**})$ $(SE^a = \pm\ 0.95)$

** Significant at the 1% level.

a Standard error of estimate.

where %P = percentage protein in the grain (N x 5.7 on a 13.5% moisture basis);

x_1 = soil nitrate-nitrogen content measured to a depth of 61 cm (kgN/ha); and y = fertilizer nitrogen applied at time of seeding (kgN/ha).

Appendix C-3b. Equation derived by Racz (personal communication) for calculation of percent protein.

$$\%P = 9.86 + 0.0586x_1 - 0.000128x_1^2 + 0.0357x_2 - 0.0000495x_2^2 - 0.000138x_1x_2$$
$(r^2 = 0.73)$

where %P = percentage protein in the grain (N x 5.7 on a 13.5% moisture basis);

x_1 = soil available nitrogen content measured to a depth of two feet; and x_2 = pounds/acre of nitrogen applied at time of seeding.

Appendix C-4. Wheat yield, observed protein content and calculated protein content.

N Applied[a] (kg/ha)	Calculated Protein[b]		Observed Protein[b]			Yield kg/ha			% of Zero N		
	1[c]	2[d]	ZT 1[e]	CULT[e]	ALKIER[f]	ZT 1[e]	CULT[e]	ALKIER[f]	ZT 1	CULT	ALKIER
0	11.3	12.8	11.4	12.0	12.1	2533	2863	1400	100	100	100
34	12.2	13.4	12.5	13.1	11.7	2930	3300	2040	116	115	146
67	13.0	14.1	12.5	14.0	12.1	3474	3468	2290	137	121	164
101	13.8	14.9	14.1	14.4	13.4	3588	3347	2560	142	117	183
134	14.4	15.6	14.8	14.6	14.6	3656	3259	2740	144	114	196
202	15.4	16.7	15.0	14.4	15.6	3965	3219	2730	157	112	195
269	16.1	17.2	15.1	14.6	16.0	3730	3273	2710	147	114	194

a An additional 10 kg/ha nitrogen was drilled with the seed as 11-48-0.
b Percentage protein in the grain (N x 5.7 on a 13.5% moisture basis).
c Percentage protein calculated according to equation supplied by Racz, Appendix C-3b, for zero tillage trials.
d Percentage protein calculated according to the equation derived by Alkier *et al*. (1972), Appendix C-3a, for zero tillage trials.
e Data obtained in nitrogen response trial where plots were under the first year of zero tillage management.
f Extracted from Alkier *et al*. (1972).

Appendix D-1. Chemical names of pesticides.

Common Name	Chemical Name
amitrole	3-amino-s-triazole
azinphosmethyl	0,0-dimethyl S(4-oxo-1,2,3-benzotriazin-3 (4H)-ylmethyl) phosphorodithioate
barban	4-chloro-2-butynyl *m*-chlorocarbanilate
benazolin	4-chloro-2-oxobenzothiazolin-3-ylacetic acid
bromoxynil	3,5-dibromo-4-hydroxybenzonitrile
captan	N-trichloromethylmercapto-4-cyclohexamide-1,2-dicarboximide
dalapon	2,2-dichloropropionic acid
dicamba	3,6-dichloro-*o*-anisic acid
dinoseb	2-*sec*-butyl-4,6-dinitrophenol
diquat	6,7-dihydrodipyrido (1,2-*a*:2',1'-*c*) pyrazinediium ion
glyphosate (MON 2139)	N-(phosphonomethyl) glycine
hexachlorobenzene	hexachlorobenzene
lindane	1, 2, 3, 4, 5, 6-hexachlorocyclohexane
malathion	diethyl mercaptosuccinate, S-ester with 0, 0-dimethyl phosphorodithioate
maneb	manganese ethylenebisdithiocarbamate
MCPA	((4-chloro-*o*-tolyl)oxy) acetic acid
mecoprop	2-((4-chloro-*o*-tolyl)oxy) propionic acid
nitrofen	2,4-dichlorophenyl *p*-nitrophenyl ether

Appendix D-1. Continued...

Common Name	Chemical Name
paraquat	1,1'-dimethyl-4, 4'-bipyridinium ion
TCA	trichloroacetic acid
2,4-D	(2,4-dichlorophenoxy) acetic acid

Appendix D-2. Latin names of plants.

Common Name	Latin Name
barley [a]	Hordeum vulgare L.
barnyard grass [b]	Echinochloa crus-galli (L.) Beauv.
black medic	Medicago lupulina L.
bluebur	Lappula echinata Gilib.
broadleaf plantain	Plantago major L.
buckwheat (tame)	Fagopyrum esculentum Gaertn.
Canada thistle [b]	Cirsium arvense (L.) Scop.
common dandelion [b]	Taraxacum officinale Weber
common groundsel	Senecio vulgaris L.
common speedwell	Veronica officinalis L.
field horsetail	Equisetum arvense L.
flax [a]	Linum usitatissimum L.
foxtail barley [b]	Hordeum jubatum L.
green foxtail [b]	Setaris viridis (L.) Beauv.
green smartweed [b]	Polygonum scabrum Moench
hemp nettle	Galeopsis tetrahit L.
lady's thumb	Polygonum persicaria L.
lamb's quarters [b]	Chenopodium album L.
oats	Avena sativa L.
perennial sow-thistle	Sonchus arvensis L.
prostrate knotweed	Polygonum aviculare L.
pygmyflower	Androsace septentuosalis L.
quack grass	Agropyron repens (L.) Beauv.
rape [a]	Brassica napus L. var annua Koch

Appendix D-2. Continued...

Common Name	Latin Name
red-root pigweed	Amaranthus retroflexus L.
Russian-thistle	Salsola kali L.
stinkweed [b]	Thlaspi arvense L.
wheat [a]	Triticum aestivum L.
wild buckwheat [b]	Polygonum convolvulus L.
wild carrot	Daucus carota L.
wild oats [b]	Avena fatua L.
wild mustard	Brassica kaber (DC.) L.C. Wheeler

a A crop grown in experimental trials.

b A major weed at one or more locations.

Appendix E-1. Soil fertility analysis of Portage zero and conventional tillage, July 29, 1969.

Nutrient	Crop	Treatment			LSD	C.V.
		ZT 1	ZT 2	Cult	(.05)	(%)
Nitrogen	wheat	14	15	15	ns	11
(kg/ha	barley	14	14	14	ns	21
NO_3^-N to	flax	26	23	14	ns	88
61 cm)	rape	12	16	16	ns	44
Phosphorous	wheat	8	7	7	ns	49
(available	barley	6	7	8	ns	35
ppm)	flax	7	8	6	ns	17
	rape	9	7	8	ns	26
Potassium	wheat	210	210	225	ns	23
(available	barley	210	175	220	ns	22
ppm)	flax	240	220	245	ns	17
	rape	260	260	240	ns	19

Appendix E-2. Nitrate nitrogen (kg/ha to 61 cm) under zero and conventional tillage, July 1970.

Location	Crop	Treatment			LSD	C.V.
		ZT 1	ZT 2	Cult	(.05)	(%)
Carman	wheat	94	75	60	ns	52
	barley	57	65	44	ns	35
	flax	45	63*	39	17	27
	rape	29	27	26	ns	22
Portage	wheat	38	39	39	ns	10
	barley	53	41	45	ns	34
	flax	44	38	41	ns	33
	rape	28	36	34	ns	24
Sanford	wheat	52	84	54	ns	103
	barley	18	27	30	ns	85
	flax	77	94	116	ns	30
	rape	49	43	47	ns	31

* Different compared to the cultivated treatment.

Appendix E-3. Available phosphorous (ppm) under zero and conventional tillage, July 1970.

Location	Crop	Treatment			LSD	C.V.
		ZT 1	ZT 2	Cult	(.05)	(%)
Carman	wheat	7	6	5	ns	41
	barley	3	6	5	ns	75
	flax	4	6	6	ns	51
	rape	5	7	6	ns	62
Portage	wheat	7	7	7	ns	22
	barley	8	9	7	ns	34
	flax	9	9	7	ns	25
	rape	10	7	7	ns	47
Sanford	wheat	11	13	12	ns	40
	barley	10	12	11	ns	29
	flax	10	12	12	ns	21
	rape	7	8	9	ns	22

Appendix E-4. Available potassium (ppm) under zero and conventional tillage, July 1970.

Location	Crop	Treatment			LSD	C.V.
		ZT 1	ZT 2	Cult	(.05)	(%)
Carman	wheat	235	235	175	ns	21
	barley	185	180	210	ns	28
	flax	180	185	235	ns	20
	rape	210	170	240	ns	32
Portage	wheat	260	245	250	ns	14
	barley	230	210	200	ns	11
	flax	220	205	250	ns	20
	rape	265	210	250	ns	25
Sanford	wheat	680	670	715	ns	22
	barley	705	625	630	ns	11
	flax	635	665	675	ns	10
	rape	585	600	585	ns	10

Appendix E-5. Soil fertility analysis of Carman zero and conventional tillage, May 9, 1972.

Nutrient	Crop in 1971	Treatment ZT 1	Treatment CULT	LSD (.05)	C.V. (%)
Nitrogen	Wheat	32	29	ns	17
(kg/ha	Barley	26	19	ns	32
NO_3-N to	Flax	40	38	ns	20
61 cm)	Rape	36	42	ns	17
Phosphorous	Wheat	7.5	6.8	ns	39
(available	Barley	5.2*	6.7	1.4	14
ppm)	Flax	5.0*	6.3	1.1	13
	Rape	3.5	6.3	ns	41
Potassium	Wheat	190	175	ns	18
(available	Barley	180	190	ns	16
ppm)	Flax	205	165	ns	24
	Rape	165	195	ns	12

* Different compared to the cultivated treatment.

Appendix F-1. Summary of weed population differences found by Schwerdtle (1970).

Species	Crop				
	Corn	Winter Wheat	Summer Barley	Oats	Field Beans
Galium aparine	+[a]			+-	+
Lamium amplexicaule			+	+	
Lamium purpureum	++	+++	+	+	+
Polygonum aviculare	-	+--			
Polygonum convolvulus	+	++	+	+	+
Polygonum persicaria	++				+
Raphanus raphanistrum			+		
Sinapis arvensis	+++	++-	++++		
Sonchus oleraceus		--			
Stellaria media	+	-	+	+	
Thlaspi arvense	++	+	++++	+	
Veronica hederifolia		+++			
Veronica persicaria	+++		+	+	+
Alopecurus myosuroides		++	-		
Avena fatua [b]				+	
Poa annua		-		-	
Cirsium arvense		--	-	-	
Convolvulus arvensis	----		---		
Sonchus arvensis		-			
Taraxacum officinale	--	--	--	--	
Agropyron repens		--	-	-	-
Lolium perenne [c]	-	-	-	-	

Footnotes on page 192.

a + indicates a significant reduction of the species population under direct seeding, - indicates the reverse situation.

b tended to be lower under direct seeding but differences not significant.

c present at only one location.

Appendix F-2. *Agropyron repens* (L.) Beauv. in plowed, rotovated, and direct seeded wheat, extracted from Schwerdtle (1970).

	Plants/m^2		
Year	Plowing	Rotovating	Direct seeding
1966	1.31a[z]	1.63a	3.87a
1967	21.36a	32.37a	251.43b
1968	1.94a	97.64b	800.37c

	Fresh Weight (g/m^2)		
Year	Plowing	Rotovating	Direct seeding
1966	8.56a[z]	42.31a	86.69a
1967	22.68a	34.68ab	821.56b
1968	7.50a	215.71b	3226.42c

z Values in a row followed by the same letter are not different at the 5% level of significance.