THE EFFECTS OF CROP RESIDUE MANAGEMENT ON ZERO TILL CROP PRODUCTION IN MANITOBA

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David Ronald Sparks Rourke

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ABSTRACT

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The Effects of Crop Residue Management on Zero Till Crop Production in Manitoba.

Major professor: Dr. E. H. Stobbe, Department of Plant Science.

The influence of three straw management practices on the emergence, vegetative growth and grain yield of spring wheat (Triticum aestivum L. cv. Sinton) and rapeseed (Brassica napus L. cv. Tower) grown under zero tillage and conventional tillage was studied over a two year period. The three straw management practices tested were burning, raking and spreading. The study was conducted on a well drained sandy loam soil as well as on a poorly drained clay soil.

The study indicated that emergence of wheat and to a lesser extent, rapeseed emergence could be reduced under zero tillage when straw was spread. The method of straw management had little effect on crop emergence on conventional tilled soils. Wheat yields were found to be similar under both zero tillage and conventional tillage. However, rapeseed yielded considerably higher when grown under zero tillage as compared to conventional tillage. The method of straw management was more important for zero tillage than for conventional tillage and was more important on clay soils than for sandy loam soils.

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INTRODUCTION

Tillage has been considered a fundamental part of crop production for thousands of years. As scientific agriculture has developed, agriculturalists in their quest to increase understanding have examined the need for tillage. Kuiper (1970) suggested that there are two main schools of thought on the purposes of tillage. He proposed that the English school considered tillage primarily as a method of controlling weed growth, whereas the German school considered that tillage was absolutely necessary to develop and maintain the soil in a physical condition compatible with plant growth.

The introduction of herbicides in modern agriculture facilitated research on soil tillage. Since all weeds could be controlled without tillage, zero tillage crop production could be evaluated. Zero tillage has been defined as a system of crop production where the crop is seeded into undisturbed stubble with the least possible soil manipulation effectively possible and in combination with chemical weed control if necessary (Donaghy, 1978).

The replacement of tillage with chemicals and zero tillage cropping techniques have shown that tillage is not necessary for the growth and development of crops. Donaghy (1973) has shown that successful crop production is possible without the use of tillage in Manitoba.

Investigations examining the effects of straw management practices on crop production using conventional tillage methods have been extensively examined but there has been no research examining straw management practices in zero tillage cropping systems in Manitoba. In 1978, a joint project was initiated to examine the effects of straw management and tillage practices on crop growth and soil physical properties. Changes in soil physical properties were determined by Elaine Gauer of the Department of Soil Science, and the evaluation on the effect of crop growth is presented in this thesis.

The objective of the present study was to determine the impact of straw management on crop growth on zero till fields. The study involved the examination of three straw management practices on the growth of wheat and rapeseed on two different soil types.

LITERATURE REVIEW

Research in Zero Tillage Crop Production

Small Grain Cereals

Production of small grain cereals using zero tillage techniques has been studied over a large number of years and in a number of countries.

In the Netherlands, Bakerman and de Wit (1970) reported that small grains, corn and green manure crops offered no risk when sown by zero tillage and yields could be expected to be equal or superior to those obtained from conventional tillage. Baeumer and Bakerman (1973) while noting yields of cereals were satisfactory from zero tilled plots, stated germination and early plant growth was sometimes found to be reduced. Germination could be expected to be reduced with zero tillage if the soil was excessively wet and cold due to the presence of heavy mulches or if toxic plant residues inhibited germination. Germination rates were found to be increased with zero tillage on light to medium soils with a friable surface.

Hodgson et al. (1977) working in Leeds, United Kingdom found no significant difference in spring barley yields when zero tillage techniques were implemented in a trial lasting 4 years. They noted that while emergence and tillering were similar to that under conventional tillage, seedling loss was greater with zero tillage, resulting in a lower plant stand on zero till plots. They also noted that higher nitrogen

applications were necessary to maintain comparable yields with zero tillage, probably due to lower rates of mineralization of soil nitrogen on zero till soils.

Finney and Knight (1973) working at Jealott's Hill, United Kingdom with winter wheat on a well drained sandy loam found marked differences in the development of the seminal root system in winter wheat on zero till plots. Slower extension of the seminal root and earlier lateral branching resulted in the production of a shallower seminal root system which persisted throughout the season. They attributed this to zero tilled soils having fewer large pores. Differences in adventitious root development, shoot growth and grain yield, however, were not observed.

Cannell et al. (1977) studied the development of cereals on heavy naturally imperfectly drained soils in southern England. These soils did, however, have tile and secondary drainage to facilitate removal of excess water. Contrary to the work of Finney and Knight (1973), they found that zero till plots had at the end of tillering, more roots below 40 cm and in the top 5 cm. As a result, in a dry year, more water was extracted from zero till soils at all depths below 40 cm. They recommended that zero tillage was suitable for the heavy soils in the United Kingdom, as zero tillage yields were always at least equal and in dry years gave higher yields of winter wheat and spring barley.

Cannell and Finney (1973) in earlier work, however, did find yield depressions of small grain cereals with zero

tillage in the first years after the establishment of zero till plots. The reasons given included: inadequate drilling equipment, large numbers of perennial grassy weeds and imperfect drainage. Yields were found to improve after about 3 years. This was attributed to increased earthworm activity allowing for better internal drainage and soil tilth. Problems with drilling equipment were overcome in latter trials (Cannell et al., 1977) by burning of the surface residues to facilitate drill penetration and soil-seed contact.

Elliot et al. (1977) following recommendations by Cannell and Finney (1973) conducted their zero tillage trials on a well drained sandy loam which was free of grassy weeds and had residues removed by burning. Emergence, early plant growth and final straw yield was found to be lower on zero till plots than with conventional tillage. Grain yields while slightly lower in the first year were higher under zero tillage in the fourth year and over all four years no significant difference was found.

Examples of small grains production using zero tillage can also be found in the United States. Davidson and Santelman (1973) found zero till to produce lower yields than plowings in a four year study in Oklahoma. They, however, attributed the lower yields to problems in seeding and weed control. Wicks (1973) from North Platte, Nebraska, worked with a winter wheat-sorghum-fallow rotation. Winter wheat yields were equal or superior to conventionally tilled treatments. Zero till treatments were planted into chemically

treated fallow, so no soil disturbance was involved. Wicks and Smika (1973) also studied the effect of zero tillage in a winter wheat-fallow rotation. Wheat yields obtained from no-till fallow yielded 7 bushels per acre more than wheat from conventional fallow. Fenster (1977) in a similar trial found the same trend, but yield differences were lower.

Schneider et al. (1978) working in North Dakota, obtained 35% more wheat when the wheat was sown directly into 14 inch stubble as compared to the situation where it was sown into flat stubble.

Canadian researchers have also examined the effects of zero tillage on small grain cereal production. Lindwall (1973) reports that yields of spring sown wheat on zero-tilled fallow were greater by 4 bu/ac in 2 year rotations and 7 bu/ac in 3 year rotations than yields on bladed fallow at Lethbridge. Bentley et al. (1978) working with barley at Edmonton, on three soil types, found no consistent differences in yield as a result of different tillage treatments over a 6 year period. They did observe, however, that at one location in one year the zero till plots became waterlogged and poor aeration resulted, causing nitrogen deficiencies and lower yields. Austenson et al. (1978) studied the effects of various drills on production of wheat without tillage. The results of the study shows that yields reflected initial stand establishment obtained with various drills and that better stands were obtained when amounts of residue on the soil surface were minimal.

Donaghy (1973) reported the results of three years work involving zero tilled wheat and barley on 3 soil types in Manitoba. Zero tillage was shown to result in improved crop stands. However, yields did not differ significantly from the conventionally tilled treatments.

Survival and yields of winter wheat in Manitoba has been greatly enhanced when sown directly into standing stubble using zero tillage cropping techniques (Stobbe, 1978). Direct seeding of winter wheat into standing stubble gives the benefit of being able to effectively capture snow in the stubble to provide an insulating layer to protect the winter wheat. This technique also allows for a greater amount of stored water in the soil to be used by the crop during the summer. Stobbe (1978) measured approximately a 20% yield advantage with zero till winter wheat as compared to conventionally sown winter wheat.

Small Grain Oilseed Crops

Only a limited amount of work has been conducted which involves zero till production of small grain oilseeds. Vez and Viellioud (1971) reported equal or higher oilseed rape yields using zero tillage in three out of four experiments on a heavy soil in Switzerland. Bakerman and de Wit (1970), however, obtained mainly decreased yields with zero tillage in six experiments conducted in the Netherlands. Zero tillage resulted in approximately 400 kg/ha less seed than conventional tillage. Experiments conducted by Donaghy (1973) in Manitoba

showed that zero tilled rape and flax always yielded at least equal to conventional tillage. It was observed that on the heavier soils tested, yields from zero tillage plots could in some years be significantly higher. Final yields of rape and flax were found to be highly correlated to the emergence obtained in these trials.

Other Crops

Perhaps the crop receiving the most attention in regards to zero tillage crop production is corn. Sorghum and soybeans have also been tested quite extensively. More limited amounts of research have been conducted on practically every type of crop grown.

Triplett et al. (1970) tested 3 corn rotations on 6 soil types over a period of 6 years in Ohio. They found that on well drained medium textured soils the highest yielding treatments corresponded to the treatment leaving the most residue on the surface. The highest corn yields were, therefore, obtained from direct seeding corn onto a killed sod. This treatment was the most effective in reducing evaporation and runoff and increasing infiltration. On sandy soils, Triplett et al. (1970) found similar yields on zero till and ploughed treatments. At one site, however, zero till resulted in an average advantage of 13 bu/acre over 5 years. This was attributed to the mulch decreasing soil movement and increasing moisture availability. On the medium and light textured soils, zero tillage produced the highest yields regardless of rotation

used. On clays, however, it was found that zero till continuous corn resulted in lower yields than continuous corn produced with conventional tillage. Corn produced under zero till conditions on the heavy clays was found to be equal to conventionally tilled corn when either a corn-oat-meadow or a corn-soybean rotation was implemented. Van Doren et al. (1976) reports the long term effects of the work initially reported by Triplett et al. (1970). After 11 years, corn yields were found to be remarkably insensitive to tillage, over a wide range of soil types, cropping systems, climates and duration of use, so long as equal plant density and weed control were achieved. They also stated that zero tillage could suffer significant yield losses on some poorly drained soils, but, apparently only when in continuous corn. Zero tillage was shown to have yield advantages on some well drained sloping soils due to conservation of water by mulch on the soil surface and stabilization of a desirable soil structure. Blevins et al. (1971) and Hill and Blevins (1973) working in Kentucky, established zero till corn on a killed sod mulch. The results of these experiments showed that zero tillage enhanced corn yields by making water more available for plant growth. Yields obtained by Hill and Blevins (1973) show that zero tillage increased corn yields by about 625 kg/ha.

Allen et al. (1977) and Unger (1978 a) at Bushland, Texas, found higher sorghum yields with zero tillage as a result of increased moisture conservation. Grain yields were also found

to increase with increasing rates of mulch cover. Allen et al. (1977) reported that zero tillage resulted in approximately 500 kg/ha more grain sorghum during the 6 year study, as compared to conventionally tilled plots.

Working at Blacksburg, Virginia, Moody et al. (1963) observed that corn plants were spindly with narrow leaves and chloratic for approximately 2 months, when grown using zero tillage with a heavy mulch. This was attributed to long exposure to the cooler temperatures, associated with zero tillage. However, after 2 months the zero till plants grew faster and by silking were 64 cm taller than conventionally tilled plants. Zero till plots with high mulch and high rates of nitrogen averaged 42 bu/acre more corn than did the conventional treatment over 3 years. Shanholtz and Lillard (1969) and Moschler et al. (1972) also working at Blacksburg, Virginia, noted that zero till corn production resulted in both higher forage and grain yields. The higher yields observed in the 11 years of testing were attributed to the more favourable moisture conditions associated with zero tillage.

Sanford et al. (1973) double cropped sorghum and soybeans onto wheat stubble in Mississippi. Yields for both zero till soybeans and sorghum were lower than conventionally tilled plots in the first two years of the trials. In the third year, weeds were controlled and soybeans in this year yielded the same as conventionally tilled soybeans. The zero till

sorghum, however, outyielded the conventionally tilled sorghum. McGregor et al. (1975) also working in Mississippi, found similar results with zero till soybeans where weeds were controlled.

Poor seed coverage resulted in a 16 percent lower corn stand on zero till plots in New Hampshire (Estes, 1972). Despite the significantly lower stand, silage yields were recorded to be 22.5 percent greater on zero till plots than conventional till plots. This was attributed to the greater amount of water available on zero till plots.

Siemens and Oschwald (1978) found emergence and early growth of corn, grown on zero till plots at Ames, Iowa, to be slower than on conventional tilled plots. It was also found, that treatments with the least amount of tillage tended to yield less. Other work in Iowa, by Mock and Erbach (1977) gave similar results. It was noted here, that when planting was delayed and the soil allowed to warm before planting, tillage systems had very similar effects on plant growth and no difference in yields was observed. It was suggested that cold tolerant corn hybrids were needed to take advantage of earlier planting sometimes possible with zero tillage.

Griffith et al. (1973) studied the effects of a number of tillage systems on corn production at 5 locations in Indiana. They found as tillage decreased and percent ground cover, increased plant growth was slowed and maturity delayed. This effect was most pronounced in Northern Indiana and either

non-existent or opposite in Southern Indiana. It seems as though the hybrid used was extremely sensitive to soil temperatures. The cooler soil temperature of Northern Indiana reduced growth, whereas, the warmer soil temperatures of Southern Indiana enhanced production.

Lal (1976) working in Nigeria, suggested that zero tillage effects on soil temperature could be beneficial. Lal found corn always to have higher yields on zero till plots. Soybeans and cowpeas in rotation with corn, also yielded higher on zero till plots. Higher yields were attributed to retention of soil organic matter, maintenance of higher levels of total nitrogen and exchangeable bases, more favourable moisture and temperature conditions and to increased infiltration and decreased runoff. These conditions were associated with zero till plots with adequate amounts of residue.

Stibbe and Ariel (1970) working in Israel, found sorghum yielded less on zero till plots in all but the driest years. The zero till plots had been established on previously tilled soils and the previous years traffic and tillage pans were a problem on zero till plots. Plants on zero till plots were characterized by shallow rooting. The shallow rooting and lack of a mulch (residues burned) restricted the amount of soil moisture available to plants, causing earlier maturity and dying off of the zero till plants. When vetch was sown in the sorghum stubble, zero till plots also yielded less.

Low yields were attributed to higher weed infestations and less favourable soil conditions on the zero till plots.

Effect of Zero Tillage on Soil Properties

Soil Fertility and Plant Nutrition

Changes in rooting habits and lack of soil mixing are the two main reasons why we might expect to find differences in the nutrient status of zero tilled plants and changes in the fertility of zero till soils.

Bakerman and de Wit (1970), Donaghy (1973), Hodgson et al. (1976), Cannell and Finney (1973) and Pidgeon and Soane (1977) have all suggested that zero till crops require more nitrogen than do conventionally tilled crops. The most common reason for this finding appears to involve the immobilization of soil nitrogen during the decomposition of organic matter. Dowdell and Cannell (1974) have also suggested reduced mineralization and nitrification of soil nitrogen in zero tilled soils due to cooler soil temperature as another reason for higher nitrogen requirements. Other reasons for higher nitrogen application include presence of weeds and compensation for thin stands or poorly developed root systems. Cannell and Finney (1973) suggested that on heavy clay soils, aeration on zero till plots has been shown to be restricted and denitrification may also be important. Loss of nitrogen by leaching has also been demonstrated to be higher on zero till plots in some circumstances.