TILLAGE EFFECTS ON SOIL MOISTURE

ABSTRACT

A literature review was completed on the effect of spring tillage on soil moisture and crop yield. The literature review shows tillage experiments are site specific and yield results are often non-repeatable even under the same soil conditions. While tillage changes soil characteristics, the effects are usually not of the magnitude to significantly affect emergence and early plant growth in experimental plots. Most experiments on effects of different tillage systems yield non-significant results or inconsistent data from year to year. Tillage experiment inconsistencies are due to the complexity of changes in soil properties caused by tillage. A summary of tillage research literature was made.

INTRODUCTION

Tillage influences crop growth and yields by changing soil structure and moisture removal patterns over the growing season. Soil structure and moisture removal changes are dependent on soil properties, types of tillage and climatic conditions. Moisture removal patterns are of most importance to semi-arid regions of Canada since moisture is usually the limiting crop yield factor (Lindwall 1984). Tillage changes soil properties and the way the environment effects those properties. Soil properties and environment determine the rate of water movement in liquid and gaseous form into and out of soil. To understand how tillage changes soil moisture, soil properties affecting moisture need to be understood. Unfortunately, the relationship between soil moisture and tillage has not been completely defined.

LITERATURE REVIEW

The relationships between crop yield, soil moisture and tillage are not completely understood. The common approach to determining effect of tillage has been to evaluate tillage using crop yield or soil moisture content as per the following studies: Al-Darby and Lowery (1984), Bauer and Kucera (1978), Blevins et al. (1971), Bond et al. (1971), Chaplin et al. (1986), Douglas and McKyes (1983), Englehorn (1946), Fenster (1964), Geiszler et al. (1971), Jones et al. (1969), Johnson et al. (1982), Kanwar (1989), Kramer and Alberts (1988), Larson (1964), Lindwall and Erbach (1983), McFarland et al. (1990), Power et al. (1958), Sarvis and Thysell (1936), Spomer (1984), Tessier et al. (1990) and Wittmus and Yarzar (1980). While most researchers agree changes in soil moisture can influence crop growth depending on soil properties and environmental conditions, no general conclusions have been made (Belvins et al. (1971), Fenster et al. (1964), Kanwar (1989), Power et al. (1958) and Van Doren et al. (1976)). Experiments done by Lindwall (1983) and Tessier et al. (1990) indicated changes in soil moisture content due to tillage are not of the magnitude to influence crop production. General conclusions about tillage and crop yield are impractical because of the many combinations of soil properties, climate and crops. This was restated by Larson (1964) in an experiment on evaluation of tillage requirements for corn production. Larson (1964) concluded to define a set of parameters which could be used to evaluate tillage practices over wide areas is not practical because of limited knowledge and the many combinations of soil, crop and climate. Even when specific soil property changes on crop yield and soil moisture were understood, the tillage required to achieve those changes may not be possible or known (Ojeniyi and Dexter (1979a)).

Numerous experiments have shown tillage affects may be dependent on environmental and soil conditions (Allen et al. (1980), Fenster et al. (1964), Johnson et al. (1984), Kanwar (1989), Power et al. (1958), Sarvis and Thysell (1936)). Kanwar (1989) reported tillage systems affected soil-water tensions in the surface layer of soil in the second year of a two-year study. However, differences were not statistically significant at the 5% level in the first year of the study. An explanation of results was not given. However, Kanwar's results did conclude variable soil water tensions increased when soil became drier under all tillage systems. The amount of change in soil water tension began to decrease at 45 kPa of soil water tension. Water tension continued to decrease further at higher values of soil water tensions (reaching up to 80 kPa), indicating climatic conditions may have affected soil water tensions. An experiment by Fenster et al. (1964) concluded effects of tillage sequence on wheat yields were variable. Fenster et al. (1964) suggested weed control was of more importance for increasing yields during dry years but less important during years when moisture was adequate. Again, climate conditions affected tillage requirements and effects. Allen et al. (1980) found conservation tillage increased fallow season soil water storage and resulted in larger crop yields in dryland wheat and sorghum crops. Power et al. (1958) concluded yearly variations in climatic conditions appeared to have a much greater effect on factors of spring wheat production than the different methods of fallow (plow, one-way, stubble mulch, fall blade and fall chisel). Sarvis and Thysell (1936) concluded crops do not always respond to a given tillage method in the same manner and degree. This was concluded to be due to differences in climatic conditions. Johnson et al. (1984) compared three conservation tillage systems, chisel plowing, till plant and no till, to conventional moldboard plowing. Soil moisture advantages with conservation tillage varied because of profile water content, delayed plant growth and soil characteristics.

Changes in soil properties due to tillage may not be of the magnitude to effect crop production. Tessier et al. (1990) reported, in general, conservation tillage significantly improved water available to crops. However, despite enhanced soil water reserve, zero tillage practices did not consistently yield more than conventionally grown wheat. Lindwall and Erback (1983) indicated tillage and planting systems often had significant effects on soil bulk density, soil moisture, soil particle size distribution and residue cover. Again, these effects were usually not of the magnitude to significantly effect emergence and early plant growth. A ten year study by Chang and Lindwall (1990) concluded saturated hydraulic conductivity and plant available water holding capacity was significantly lower and bulk density was higher at the 30 to 60 mm depth in no till treatments than in the conventional tillage regime. However, none of the soil properties approached values that would limit yield of Winter Wheat crops. In addition, Chang and Lindwall (1990) found soil physical properties at a depth of 0 to 30 mm and 90 to 120 mm (below the tillage zone) were not significantly different among tillage and crop rotation treatments. Englehorn (1946) indicated the storage of soil moisture, either under summer fallow or continuous cropping, was not greatly affected by type of tillage.

Most experiments on tillage relations to soil moisture or crop yield are neither consistent nor show significant differences among different tillage trials. Kanwar (1989) stated although a no till system of tillage tended to show more soil water storage in the soil profile, no significant statistical difference was found between the tillage systems on the basis of two years of field data. Kanwar's (1989) results showed tillage systems have little or no effect on soil water storage in the soil profile. Kramer and Alberts (1988) reported results of a six year study of three tillage systems (moldboard plow, chisel plow and no till). They concluded tillage systems had no significant effect on plant population or grain yield. Chaplin et al. (1986) found no significant effect of tillage system (moldboard plow, chisel plow, ridge plant and no till) on irrigated corn or soybean yields. Bauer and Kucera (1978) concluded storage of soil water under annual cropping in North Dakota was not significantly affected by tillage method, nor was soil water content consistently greater under any one tillage method. Al-Darby (1984) stated plant emergence was not significantly different among moldboard plow, chisel plow, till plant and no till tillage practices. In addition, yield was only significantly higher on the no till compared to the moldboard plow one of two years.

Experiments showing significant yield responses to tillage are usually site specific and not repeatable in other soil conditions. Blevins et al. (1971) indicated no till treatments had higher volumetric moisture content to a depth of 60 cm during most of the growing season. The largest differences occurred in the upper 0 to 8 cm depth. However, Blevins et al. (1971) also suggested soil moisture curves indicated two different water withdrawal patterns under the two contrasting methods of tillage, indicated crop type may have influenced results. Geiszler et al. (1971) stated the type of seedbed preparation on stubble land has a marked influence on wheat yields. However, seedbed preparation included fall and spring trials. Maule (1990) suggested over winter moisture catch can contribute to significant increases in spring soil moisture content depending on the tillage treatment.

Most tillage experiment inconsistencies are due to the complexity of the changes in soil properties caused by tillage (Douglas and Mckyes (1983)). Chang and Lindwall (1990) indicated from a literature review, soil property changes due to tillage are related to several things. Those things include soil type, type of tillage equipment, tillage depth, soil conditions such as moisture content at the time of tillage and climatic conditions. Bauer and Kucera (1978) concluded inconsistencies in relative grain yield differences among tillage treatments over a period of years were, in part, associated with inconsistent differences in soil properties produced by given tillage treatments from one year to another. Inconsistencies were concluded to be likely associated with the presence of soil water at the time of tillage and climatic conditions - primary water supply, water distribution and temperature. Van Doren et al. (1976) stated researchers found conservation tillage practices resulted in lower yields on poorly drained soils and produced higher yields on well drained soils. Rydberg (1990) concluded ploughless tillage reduced the rate of evaporation, mainly by reducing slaking of the surface. Slaking was a result of higher content of undegraded crop residues and better stability of soil particles. Rydberg (1990) also concluded ploughless tillage could reduce evaporation more on a silty clay loam than on a heavy clay, indicating soil type influenced results. Burwell et al. (1966) stated the amount of moisture in the soil when it is tilled affects the resulting pore space. When soil moisture content level was different than the moisture content normally favourable for working a seedbed the pore space increased, indicating soil changes in pore space were greater than when tillage was performed at the favourable moisture content level. Ideal soil moisture content was not outlined.

Other soil and cropping factors may affect crop yields more than soil moisture content changes due to tillage. Ojeniyi and Dexter (1979a) stated cropping history showed continuous cereal crops produced larger soil particles and voids when periods of pasture or fallow are included in the rotation. Ojeniyi and Dexter (1979a) attributed the results to smaller organic matter content under continuous cropping. Greater frequency of tillage after fallow was also a contributing factor. Several studies have been conducted to assess effects of tillage systems on hydraulic properties of soils (Adeoye (1982), Belvins et al. (1983), Hamblin and Tennant (1981), Wittmus and Yazar (1980)). Allmaras et al. (1977) reported an increase in hydraulic conductivity with chisel plowing. Ehlers et al. (1980) concluded tillage may change soil bulk density, shoot and root growth and the water uptake pattern of a crop. McFarland et al. (1990) concluded long term effects of tillage practices on soil physical properties may depend on the associated cropping sequence and more research on interactive effects was required. Spomer and Hjelmfelt (1984) observed on the Treynor, Iowa research watersheds soil moisture was affected more by cropping (grass vs. corn) than tillage (conventional versus till plant). However, neither treatment caused significant differences.

In addition to soil moisture changes, tillage may affect other soil physical and chemical properties. Changes in soil chemical properties can affect crop yield and crop responses to tillage. Bauer and Kucera (1978) suggested in addition to physical properties, certain chemical properties of soil can be affected by tillage, especially when tillage affects soil temperature.

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Site soil properties will affect how a tillage system changes the soil properties. Ojeniyi and Dexter (1979a) indicated there is an optimum water content were tillage produces a maximum number of small soil particles and a minimum number of large voids. This was equal to a gravimetric water content of around 0.19 of the soil's plastic limit. Ojeniyi and Dexter (1979a) also indicated greatest total macro porosity was produced in the range of water contents 12.6 to 18.3 per cent on an Urrbrae loam soil (17 per cent clay, 32 per cent silt and 51 per cent sand). Even if the effects of tillage and soil conservation were completely understood, other cropping factors such as wind and water erosion of soil must be considered. Russell (1961) states researchers generally accept that a soil particle size range of 1 to 5 mm is required for seedbeds. However, surface conditions effect wind erosion and stability of dry soil particles. Ojeniyi and Dexter (1979a) concluded to conserve moisture, one wants to till soil to minimize proportion of voids larger than about 8 mm. Dry soil particles 0.84 mm in equivalent diameter and smaller are generally considered erodible (Chepil 1955).

SUMMARY

A literature review on the effects of tillage on soil moisture content and crop yield was completed. While research varies with different soil conditions and crop types, the following states are consistent with most literature:

The relationships of crop yield and soil moisture are not well understood. However, the common approach to determining the effect of tillage has been to evaluate the tillage using crop yield or soils moisture content.

Changes in soil properties due to tillage may not be of the magnitude to effect crop production.

The results of numerous experiments on tillage relations to soil moisture or crop yield are neither consistent or show significant differences among different tillage trials.

While some experiments have shown significant tillage trials crop yield difference, experiments are usually non repeatable even at the same site. Numerous experiments have indicated tillage effects may be dependant on site environmental and soil conditions.

Most tillage experiment inconsistencies are due to the complexity of the changes in soil properties caused by tillage.

Other factors such as cropping history may affect crop yields more than soil moisture content changes due to tillage.

In addition to soil moisture changes, tillage may affect other soil physical and chemical properties.

The site specific soil properties will affect how a tillage system changes the soil properties.

Non significant differences between no till and conventional tillage experiments may be due to evaporation control caused by tillage.

Over winter moisture catch can contribute to significant increases in spring soil moisture content depending on the tillage treatment.

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