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THE CONSERVATION CHARACTERISTICS OF MINIMUM TILLAGE PRACTICES

by

CALVIN WAYNE LINDWALL

A THESIS

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FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "The Conservation Characteristics of Minimum Tillage Practices", submitted by Calvin Wayne Lindwall in partial fulfilment of the requirements for the degree of Master of Science.

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ABSTRACT

A small-plot experiment with eight fallow treatments randomized in six replicates was conducted at the Lethbridge Research Station on a clay loam soil from 1967 to 1974, inclusive. The treatments were carried out on a fallow-spring wheat rotation, with chemical and tillage treatments being applied throughout the fallow season to maintain good weed control. The chemical applied was primarily paraquat (12-16 oz in 25 gal water/ac), occasionally combined with 8 oz of 2,4-D ester or 8 oz of bromoxynil + MCPA ester. Weed control by tillage was maintained with the blade cultivator and a one-way disc. The fallow treatments were designed to take advantage of optimum use of herbicides and tillage throughout the fallow season. Fall tillage was designed to provide better moisture intake from snowmelt. All treatments received a spring cultivation for seedbed preparation. Detailed observations regarding the effects of tillage treatment on soil moisture, quantity and orientation of crop residue, NO_3-N status, weed growth, and various crop growth parameters were noted.

Fallows which received only chemical weed control conserved significantly more crop residue and maintained the highest soil moisture status of any fallow treatment. Treatments involving the one-way disc conserved significantly less crop residue than all other treatments and generally left fallows susceptible to wind erosion. Chemical fallow with a fall-blading produced significantly higher yields and taller crops in five of the seven years studied.

Poorer moisture conservation of fallows involving only mechanical tillage was generally reflected in crop yields. The trend was for lower NO_3-N values in the spring prior to seedbed preparation for the wholly chemical fallow, but overall differences were not significant. Effective weed control was generally more important than soil physical effects resulting from fallow methods. Fall-blading did not generally improve moisture intake from snowmelt but did result in more effective control of winter annual weeds. If more suitable herbicides become available that will economically control all weeds during the summerfallow year with no detrimental effect on subsequent crops, it may be more advantageous to summer-fallow without tillage.

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INTRODUCTION

1.1 Tillage in General

Each year in Canada, more than 250 billion tons of soil are turned or stirred in the production of food and fibre. In an increasingly energy conscious world one can appreciate this vast expenditure given to soil manipulation.

Tillage is a cultural practice generally taken for granted as a necessary phase of agricultural production. Yet most of today's tillage machines have been developed on the basis of traditional field experience rather than a technical understanding of soil-machine relationships. But what are the objectives of tillage; the following are the reasons generally given for tilling the soil:

1. to move the soil for seed insertion
2. to manage crop residue
3. to alter physical condition of soil
4. to control weed growth
5. to add soil amendments
6. to reduce wind erosion through emergency tillage
7. to control insects and diseases

Until recently, little attention has been given to the possible adverse effects of tillage as a consequence of the above objectives. If tillage increases soil productivity then one must understand the processes involved, as well as determine if tillage is the best way of reaching this higher productivity.

Upon observing many adverse effects of intensive tillage practices, researchers in the United States and many parts of Europe began testing the concept of reduced or minimum tillage (see Glossary). Under a variety of crops and growing conditions, minimum tillage was found to reduce compaction and lessen production costs. The growing concern over soil compaction, coupled with the availability of suitable herbicides, has resulted in an estimated 12 million acres coming under minimum or zero tillage (see Glossary) systems in the United States today.

1.2 Tillage in Western Canada

Most of the agricultural crops on the prairies are grown under semiarid conditions; this implies that rainfall is the limiting factor in grain production. In the early 1890's it was observed that land left uncropped for one season produced higher yields and resulted in fewer crop failures than did continuously cropped land, provided the land under fallow was kept free of weeds. Thus the practice of summerfallow (see Glossary) became commonplace on much of the semiarid prairies as a necessary practice for maximizing production.

Summerfallowing has traditionally involved extensive tillage in order to control weeds, loosen the soil, and ultimately eliminate much of the previous crop residue. The drought and winds of the 1930's forced farmers and researchers alike to look to alternate methods of fallowing that would conserve crop residues and prevent erosion. Stubble mulching (see Glossary), whereby weeds were controlled with tillage machines designed to minimize trash burial, became widely adopted throughout the Great Plains region.

Although dryland cultural practices have advanced significantly since the black fallow era, the emphasis is still on research to improve farming techniques so as to reduce the variability and at the same time maximize crop production. Because of this and research work elsewhere, it was inevitable that Canadian research institutions began to look at possible application of minimum tillage to dryland cereal production. The theory of maximizing residue conservation by minimizing tillage, warrants further study as an erosion preventative and a possible means of improving soil moisture conservation. The fact that little is known regarding the effects that little or no tillage will have on soil physical and chemical characteristics and ultimately on crop production makes this area of research a challenging and fascinating one indeed.

1.3 Objectives of Study

In 1967 a minimum tillage project was initiated at the Agriculture Canada Research Station at Lethbridge. The objective of the project was to find methods of summerfallowing that minimized operational requirements for tillage and improve erosion resistance of field surfaces, moisture conservation and yield of spring-sown cereals.

The study reported herein utilizes some of the data of the above mentioned project in an attempt to characterize several minimum tillage practices as they relate to residue and moisture conservation.

More specifically the objectives were:

1. to determine the extent of fallow tillage necessary for maximum moisture conservation.
2. to determine when during the fallow cycle tillage is most effective for maximizing moisture conservation and/or maintaining good weed control.
3. to determine the relationship between surface residues and moisture conservation.
4. to determine the effects of various tillage regimes on the nitrate status of soils.
5. to determine if the soil physical and chemical characteristics created by various fallow tillage practices are reflected in crop growth.
6. to establish the necessary criteria for one to define the optimum tillage system for a given set of climatological and soil conditions.

CHAPTER 2

SURVEY OF LITERATURE

Minimum or zero tillage has been studied extensively in the corn and cotton producing areas of the United States. However, this review will consist primarily of research related to conservation tillage in the semiarid regions of the Great Plains of North America. The survey will summarize the direct and indirect effects of tillage and lack of tillage in relation to cereal production with particular emphasis on residue conservation and erodibility, moisture conservation, infiltration, weed control, soil compaction, soil temperature, and soil nutrient status.

2.1 Residue Conservation and Erodibility

Most farmers and researchers of the semiarid prairies consider the practice of summerfallow necessary for maximum cereal production (1,3,9,10,25,37,42). The goal of the farmer then is to choose a tillage system that will economically control weeds and at the same time optimize moisture and residue conservation so as to prevent erosion during the fallow period.

2.1.1 Erosion Protection

Studies have shown that 1500 lb/ac of erect or semi-erect stubble are necessary to provide adequate erosion protection on medium textured soils (37). Larger quantities are necessary to adequately protect most lighter soils and some heavy clay soils. The condition of the field surface is also important in the assessment of soil erodibility. A field on which at least half of the surface clods are larger than 0.04 inches will resist most strong winds (37). If a field contains two thirds or more soil particles less than this size then a light wind may easily erode the surface.

As tillage is primarily a residue (see Glossary) reduction process, researchers have made extensive studies of tillage machine practices and their related effects. Anderson (11,12,13,14,15,16, 17,18,19,20) conducted numerous studies evaluating the residue conservation characteristics of tillage machines. He found that under normal conditions sweep-tillage machines bury 10 to 15 percent of surface residue per operation, heavy-duty cultivators bury from 15 to 26 percent, and the one-way disc buries up to 50 percent per operation (13,37). A farmer in the brown soil zone of the prairies can expect to have 1800 to 2500 lb/ac of trash cover at the beginning of the fallow period if a spring wheat crop yielded 30 bus/ac (37). Considering these figures, plus the fact that at least three tillage operations are necessary for adequate weed control in this area (73), the conclusion is made that even subsurface tillage machines provide less than adequate erosion protection by the end of the fallow period. Conventional seedbed preparation (see Glossary) practices further reduce surface residue levels, increasing the hazards of erosion by the spring winds, typical on southern prairies.

2.1.2 Residue Orientation

The quality or orientation of crop residue is also very important to soil conservation. Several studies have reported that anchored, upright stubble is much more effective in holding snow than equal amounts of loose or flattened residue (4,5,7,9,53,85,87,108,109). Many of the implications of this fact will be discussed further in this chapter under the headings of moisture conservation, infiltration, and soil temperature. However, the above observations suggest that conventional tillage methods provide very little upright residue which is particularly crucial during the second winter of the fallow cycle. Studies by Anderson at Lethbridge (12,13,18,20) indicate that if the number of operations can be reduced to two or less with the wide-blade cultivator and one with the heavy-duty cultivator, then upright residue orientation can be maintained. This implies, that in order to maximize the snow-holding capabilities during the fallow cycle, alternate methods of weed control are necessary.

2.1.3 Minimum Tillage

At Swift Current, Anderson (5) found that chemical summerfallow conserved 58 percent of original residue, while sweep tillage only conserved 23 percent by the end of the fallow period. Another study on a heavy clay soil at Regina showed that chemical summerfallow conserved 91 percent of the original residue while normal tillage methods only conserved 24 percent (74). Further studies at Swift Current indicate that chemical fallow plots contained less fine, erodible soil particles than those plots which received conventional tillage (4,5,7,9).

2.1.4 Seedbeds and Seeding

The most common objective of any tillage system is that of seed insertion. The high levels of surface residue associated with stubble mulch and chemical fallow require some degree of specialized seeding machinery for adequate seed placement. Anderson and Smith (17) assessed the performance of several seed drills in extreme quantities of stubble mulch. They found that conventional seed drills such as a semi-deep furrow hoe drill and a one-way disc seeder performed effectively in residue quantities as high as 4000 lb/ac. A double disc press drill gave good results in quantities up to 2000 lb/ac. Anderson concluded that a deliberate reduction of surface residue should be carried out only when seeding methods or other considerations require.

Early studies by Anderson and Wenhardt (4) found that pre-seeding tillage and seeding significantly increased soil erodibility. A recent study at Swift Current indicated that plots receiving conventional seedbed preparation produced no better yields than those receiving no seedbed preparation, provided weeds were controlled at the time of seeding (10). The same study also revealed that a variety of commercial seed drills provided effective seed placement in plots receiving no preseeding tillage.

2.2 Moisture Conservation

Moisture conservation is considered to be the primary benefit of summerfallow in the semiarid region of the Canadian prairies. The great quantity of published work on the subject indicates that no one system of summerfallowing may be universally applied as the best system for moisture conservation.

2.2.1 <u>Moisture's Contribution to Yield</u>

The importance of available soil moisture at seeding time has been well documented for most semiarid regions. Staple et al (93,94) determined from longterm studies at Swift Current that between 25 and 50 percent of the total moisture consumption by a spring wheat crop came from soil moisture reserves. From the same study, a regression analysis showed an increase of 3.5 bus/ac for each additional inch of water available to the crop. In a later study, the same scientists found that a better estimation of yield was possible by utilizing rainfall distribution data as well as the zones of stored soil moisture (63). They discovered that June and July precipitation, along with the quantity of moisture stored below 12 inches, had the greatest effect on yield variability. An early South Dakota study by Pengra (81) using 25 years of weather and yield data showed preseason precipitation to be as significant in wheat production as that received during the growing season. However, he did not state the relationship between preseason precipitation and the percentage of the moisture stored as available water.

Utilizing the data from 90 different experiments, a Washington scientist determined that available spring moisture and seasonal precipitation contributed equally to the yield of spring wheat (62). Further analysis of the same study indicated that 4 inches of water were required to grow a wheat crop to the heading stage and each additional inch increased the yield by approximately 6 bus/ac. Two similar studies of yield and moisture data on the Great Plains indicated that each inch of available water (see Glossary) above

4.5 inches produced an average yield increase of 2.5 bus/ac (60,71).

2.2.2 Inefficiency of Summerfallow

Although results vary, several long term studies show that, in general, fallowing is very inefficient in storing precipitation. An extensive study of 450 crop-fallow periods in ten states on the Great Plains by Mathews and Army (72) found that the average wheat-fallow cycle stored 16.3 percent of the precipitation received during the fallow period. They concluded that a 20 percent efficiency would be optimum for much of the Plains region. Early work at Swift Current by Staple et al (93,94) showed the average moisture conservation over a 21-month fallow period was 21 percent. Their research also indicated that the conservation percentages progressively decreased throughout the intervals of the fallow cycle. This seems reasonable since the relative moisture gains will naturally become less as the soil profile progressively fills with water. Common to several studies was the fact that the overall conservation efficiency of fallowing was highly correlated and inversely related to the soil moisture status early in the fallow cycle (57, 71, 72, 94). This suggests that when substantial rainfall occurs during or immediately after harvest, it would be difficult to justify summerfallow on the basis of moisture conservation alone.

2.2.3 Residue Effects

As was indicated previously, fields having upright surface residue are more effective in holding snow and reducing erosion than those free of any stubble mulch. The maintenance of high quantities of surface residue may be highly related to moisture conservation as well as several other considerations to be discussed later. Several studies have reported that the greater snow-holding ability of a stubble mulch has resulted in increased moisture conservation during the winter period (53,85,108,109). Willis et al (108, 109) found that snow was an effective insulator in preventing moisture loss and that the insulative effects increased with snow depth. They also indicated that increased stubble height hastened the initiation of snowpack runoff and decreased the amount of time required for complete melting. This may limit the moisture conserved, particularly if the soil is relatively wet at the time of thawing. These factors which influence spring thaw may be very important as this is the time during which a large portion of winter precipitation is lost due to runoff.

Surface mulches have increased moisture conservation by reducing evaporation. A greenhouse study revealed that wheat straw residue completely covering a wet soil surface reduced evaporation by 57 percent when compared to the soil surface with no residue (100). Greb (52), using a solar still technique, determined that an application of 1000, 2000, and 3000 lb/ac of wheat straw or 30, 60, and 90 percent soil coverage reduced evaporation losses from a wet soil surface by 16, 33, and 49 percent respectively, for a 20-day period when compared with no straw. He also found no particular advantage to having more than 100 percent soil coverage. A recent field study by Black (33) indicated a positive correlation of soil moisture status at the completion of the fallow period to increasing residue levels up to 6000 lb/ac. Research by Greb et al (54), using data from 16 fallow-winter wheat cycles, showed that surface residue levels of 2400, 3600, and 5500 lb/ac may result in net moisture gains of up to 1.0, 1.2, and 2.0 inches of water respectively. They indicated that the increased moisture was generally reflected in yields, however, in wet years the high mulch rates may in fact inhibit yield as a result of temperature depression. In a similar study, Black (32) found little moisture or yield advantage from mulch quantities greater than 1500 lb/ac. Army et al (22) observed improved soil moisture in the seed zone and reduced surface crusting as a result of stubble mulch tillage. Their theory was that standing stubble was more effective in reducing evaporation than prostrate residue because of reduced air circulation. Several of the above studies emphasized that mulches only reduce evaporation under wet soil conditions and, in fact, mulches may have an adverse effect on crop growth in cool, wet years.

2.2.4. Tillage Effects

Although several researchers have found that the type of tillage machine has little effect on soil moisture storage, there has been considerable study done on the importance of the amount and timeliness of tillage in fallow systems. Early studies by Wiese and Army (105) found no particular moisture advantage of mulched plots over bare plots. Staple et al (94) observed that stubble mulch conserved 37 percent of winter precipitation while bare fallow only conserved 9 percent. McCalla and Army (66) indicate it is difficult to generalize as to the best type of tillage method for moisture conservation. A tillage system which provides good weed control and effective erosion protection will generally be conducive to good moisture conservation.

2.2.5 Timeliness of Tillage

Early studies recommended fall tillage for best moisture conservation (42,44,53,64,71). In most cases the additional winter precipitation saved was thought to be largely due to better weed control rather than to tillage directly. However, under conditions when runoff may be a problem, fall tillage is recommended to permit optimum moisture infiltration (42,44). A recent study by Lindstrom et al (64) indicated that fall chiseling (see Glossary) prior to cold winters increased over-winter storage by 3 inches of available water when compared to no fall tillage. The fact that similar results were not obtained in mild winters possibly indicates that the tillage resulted in earlier spring thawing, minimizing losses due to runoff.

2.2.6 Minimum Tillage

The emphasis on improving moisture conservation of fallowing resulted in numerous studies involving minimum tillage and chemical fallow. Early studies by Wiese and Army (105,106) on silty clay loam soils in Texas indicated that chemical fallow conserved no more moisture than did stubble mulch fallow or disced fallow. Army et al (22) found, in a later study, that stubble mulch tillage and zero tillage resulted in improved moisture in the seed zone when compared to conventional tillage, but there was no moisture difference below a 2 inch depth with any of the tillage methods studied.

Black and Power (31) concluded that stubble mulch tillage was superior to no-tillage or tillage combined with some chemical weed control. They attributed the reduced moisture conservation of chemical fallow to poor weed control with the available herbicides. Studies by Anderson (5,9) at Swift Current indicate that chemical fallow did not improve moisture status during summerfallow; however, poorer weed control was noted with herbicides. Several studies by Molberg et al (73,74) on a variety of soils showed that if weeds were adequately controlled then moisture conservation and crop yields on chemically fallowed plots were as good as on those plots receiving only mechanical tillage.

As a result of the availability of effective residual and non-residual type herbicides, recent work with chemical fallow indicates a definite moisture advantage. Nebraska studies of winter wheat on fallow by Smika and Wicks (86,104) found moisture storage efficiencies of 25, 32 and 44 percent during the 14-month fallow period with treatments involving plowing, stubble mulching, and zero tillage respectively. These moisture differences were reflected in subsequent crop yields and apparently the residual effects from the triazine compounds were not a problem on this silt loam soil. Unger et al (101) determined from a recent study on a clay loam soil in Texas that summerfallow involving only herbicides or herbicides with one subsurface tillage operation conserved 39 percent of fallow precipitation compared to mechanical tillage methods which only conserved from 14 to 24 percent. Unger concluded that as a result of the additional moisture conserved with zero tillage, the normal preplant irrigation could be eliminated. An Oklahoma study also indicated improved moisture conservation on chemical fallows; however, the high levels of wheat straw remaining on the soil surface at the end of the fallow period were thought to inhibit subsequent crop growth (41). Extensive surveys on the subject by Baeumer and Bakermans (23) suggest that greater soil water storage may be attained with chemical fallow only under the following conditions:

> first, when cumulative evaporation during drying intervals is less with an undisturbed upright standing stubble than with a residue cover knocked down by subtillage; second, when more frequent rains are prevalent, since mulches are of little value for water conservation during extended dry periods.

The literature would also suggest that the obvious additional condition one could impose is that of effective weed control; essential for optimum moisture conservation.

2.3 Effects on Infiltration and Water Erosion

2.3.1 Moderation of Rainfall Intensity

Closely associated with moisture conservation are the effects that various tillage or no tillage practices may have on soil infiltration characteristics. The importance of residue conservation for erosion control has previously been suggested. Surface mulches also exhibit a significant moderating effect on water erosion, resulting in improved infiltration under situations of high intensity rainfall. McCalla and Army (66) report that the dispersive action of raindrops hitting a bare soil are due to the slaking of the dry soil when wetted and the breaking down of soil particles. A surface mulch reduces the intensity of rainfall, thereby retarding the slaking and sealing process, increasing the infiltration potential.

In a simulated rainfall of 2.5 in/hr on a highly permeable clay loam soil, Barnes et al (27) measured the infiltration rates with various summerfallow practices. They found that the infiltration rates were 1.52, 1.28, and 0.98 in/hr for zero tillage, plow tillage, and sweep tillage respectively. Under similar conditions, Swamy Rao et al (98) also reported greater infiltration with zero tillage. McCalla and Army (66) indicated that several other researchers found that stubble mulching and zero tillage generally increased moisture infiltration into most soils. Alley and Chamberlain (3) also observed from several studies in Wyoming that water intake rates were greater on chemical fallow than on clean cultivated or plowed fallows.

2.3.2 Homogeneity of Soil Pore Space

Baeumer (23) attributed the high infiltration rates on zero tilled soil to the continuity of the draining pores. Although zero tillage normally reduced total pore space (see Glossary), Baeumer indicated that the continuity of pores in untilled soils was more important than the total volume of pore space. This continuity of pores was not evident in conventionally tilled soils. Baeumer and Bakermans (23) also reported that most untilled soils had lower soil water tensions, implying less resistance to water and nutrient uptake by plant roots and a higher conductivity of soil water. Papendick et al (79) indicate that mobility of water in the root zone is often more important than availability. They found that under field conditions, water extraction by wheat may reach -40 bars or lower in certain situations.

2.3.3 Reduction of Water Erosion

The improved infiltration characteristics of stubble mulch and zero tilled soils have obvious implications in reducing water erosion from runoff. Mannering and Meyer (70) observed the effects of six rates of wheat straw on soil erosion for a highly permeable silt loam field with a 5 percent slope. A simulated rainfall of 6.25 inches was applied at 2.5 in/hr. Residue levels of 1, 2, and 4 tons per acre maintained high infiltration with no erosion, while the 0, 0.25, and 0.5 ton levels lost 12, 3, and 1 ton of soil per acre respectively.

2.4 Soil Compaction Effects

2.4.1 Purpose of Study

In recent years, compaction has received a good deal of attention in Europe and the Western United States in terms of its related effects on moisture, aeration, temperature, nutrients, soil strength, and ultimately crop yield. European scientists first began testing the concept of minimum and zero tillage in an attempt to alleviate the excessive compaction noted with intensive tillage practices (23,26,96). As previously indicated, zero tillage is practiced widely in the corn and cotton growing areas of the United States, as a system which reduces compaction and lowers costs of production.

2.4.2 Stubble Mulch Systems

The rapid adoption of stubble mulch tillage resulted in a growing concern as to the effects that the lack of soil inversion may have on soil porosity and density (66). McCalla and Army (66) reported that, depending on the soil and location, researchers found compaction effects ranging from nil to severe on fields receiving only subtillage. An early study by Diebold (44) noted severe tillage hard pans (see Glossary) as a result of tillage in soils containing greater than 50 percent available moisture. Early work by Cook et al (39) also found that compaction resulting from conventional tillage practices may reduce yields. Later research indicated that many conventional tillage systems had adverse effects on soil density and compaction; however, these effects were not noted on minimally or untilled soils (98,99).

2.4.3 Minimum Tillage Systems

Bakermans and de Wit (26) found that soils naturally compacted under no-till conditions resulted in better trafficability, more suitable working days, earlier sowing, greater moisture conservation, and reduced erosion. However, other European studies observed that many of the benefits of no-tillage were outweighed by the problem of inadequate seed placement in untilled soils (82,96).

In a Montana study, Baker et al (25) concluded that one preseeding tillage operation was necessary to facilitate adequate seed placement on chemically fallowed fields. A Washington study on a silty clay loam soil indicated no measurable bulk density differences between sweep tillage and chemical fallow (67). However, McCalla et al (66) did observe reduced crusting on the chemical fallows as a result of slower drying after rains. Anderson (5,8,9,10) and other Canadian researchers generally agree that on the prairie soils tested to date, no adverse effects of minimum or zero tillage on soil physical characteristics have been observed. Stobbe (97) and others have suggested that compaction associated with or without tillage is not likely to be a problem because of the severity of prairie winters and the spring frost action.

2.5 Weed Control

2.5.1 Importance

One of the reasons for summerfallow in any crop rotation is to permit the reduction of weed populations which would normally appear in the subsequent crop. The importance of weed control is emphasized by the fact that weeds cost farmers millions of dollars each year in lost production, expensive herbicides, and grain dockage. Several studies have noted that weed control is the primary concern in the selection and application of any tillage or no tillage system (1,3,5,6,9,10,25,31,49,51,73).

2.5.2 Conventional Tillage Practices

Aasheim (1) observed that shallow rooted weeds were more of a problem to control with stubble mulching than with plowing or one-waying. McCalla et al (66,67) concluded that weed control with stubble mulching was more difficult than with plowing because the weed seeds were not buried nor were the weed seedlings and the soil sufficiently separated by sweep tillage. Cook et al (39) reported that the moldboard plow was still the best once-over tillage method for weed control, in spite of its other disadvantages. In a continuous cropping study, Bond et al (35) found that crops grown on seedbeds prepared by plowing produced greater yields than those prepared by stubble mulching; a direct result of better control of the grassy-type weeds. Fenster et al (49) also reported that sweep machines did not control the annual grassy-type weeds. They obtained the best weed control and subsequently best yields on those plots tilled in late fall or early spring with the one-way disc or plow. Sweep tillage was found to be most effective for weed control when the soil contained less than 50 percent of its water holding capacity.

2.5.3 Number of Tillage Operations

Molberg et al (73) concluded that from three to four summer-fallow tillage operations were necessary to maintain weed control on the prairies. Dew (43) also found that four tillage operations in the black soil zone usually controlled weeds and that up to twelve operations had no effect on crop yield. Several scientists agree that the primary and sometimes single benefit of tillage is weed control (5,8,9,51,73,74,97). Thus, if weeds may be controlled economically with herbicides, then much of the normal cultivation may not be necessary. Previously reported was the fact that fall tillage often resulted in improved moisture status as a direct result of better control of winter annual weeds. Anderson (6) found that late fall applications of 2,4-D were very effective in controlling winter annual forms of stinkweed and flixweed. As well as conserving more surface residue than fall tillage, the fall spraying was more economical.

2.5.4 Chemical Control

Many of the early studies reported reduced moisture conservation and yields on chemically fallowed fields; this was generally due to poor weed control with available herbicides (5,9,31,73,74,105, 106). Herbicides such as 2,4-D were not effective in controlling the persistent grassy-type weed varieties such as downy brome and green foxtail. Residual type herbicides such as atrazine are commonly used in the corn belt of the United States, but application to small grain production has met with limited success because of the carry over of toxic residues (48). Many non-residual type herbicides such as paraquat have successfully been used in chemical fallow studies for all-inclusive weed control (5,9,10,23,26,48,101,104). These herbicides are not yet economical forms of weed control to be of practical significance to the farmer.

2.5.5 Weed Populations

Baeumer and Bakermans (23) indicate that zero tillage systems may significantly alter weed populations. An untilled soil may prevent buried weed seeds from germinating and should result in reduced populations of annual weeds. They do report, however, that incomplete weed control may result in large populations of perennial weed seeds building up in untilled soil. Serious weed infestations may then result from seeding methods requiring substantial soil manipulation. The literature review would suggest that without the problem of weed control the formulation of the ideal tillage system would indeed become relatively simple.

2.6 Soil Temperature Effects

The importance of tillage methods on residue conservation has previously been emphasized. Mulches have a moderating effect on the temperature regime of a soil (66). Soil temperature may directly influence moisture conservation, residue decomposition, and several other biological factors.

2.6.1 Crop Growth

Several studies have reported the temperature effects of surface mulches in relation to crop growth. Greenhouse studies by Dubetz et al (45) generally indicated that rate of emergence of cereal grains was directly related to soil temperatures ranging from 6 to 24° C. Anderson and Russell (15) reported delayed maturity and depressed wheat yields from field studies on plots that had 4000 to 5000 lb/ac of surface residue. They indicated that reduced soil temperatures from seeding to heading was a major factor in the yield depression. Greb et al (54) also found that mulch quantities of 5000 lb/ac may reduce soil temperature by as much as 5° C, and in cool wet years this reduced temperature may depress yield. Similar results were obtained in an earlier study by Smika et al (87). Although recent work by Whitheld and Smika (103) found that soil temperature adversely affected the uptake of some nutrients; they concluded that the increased moisture availability under mulching overcomes any depressive effects the residue might have. Davidson and Santelmann (41) reported that mulch rates as low as 2000 lb/ac on the soil surface at seeding time may depress spring wheat yields. However, they did not suggest that the entire reason for the yield depression was a reduced soil temperature. Baeumer and Bakermans (23) noted that mulches when compared to bare soils may increase soil temperature during winter or exceptionally cool conditions. As a result of several minimum tillage studies it was observed that soil temperature differences were not significant in the assessment of tillage treatments (3,5,8,9,10).

2.6.2 Microbial Activity

McCalla and Army (23) state that microbial activity is directly related to soil temperature, affecting the rates of organic matter decomposition, ammonification, nitrogen-fixation, and nitrification which will be discussed in the next section.

2.7 Soil Nutrient Status

2.7.1 Nitrates and Crop Growth

Although soil nutrients are not generally a limiting factor to cereal production in semiarid regions, a good deal of attention has been given to the effects of numerous cultural practices on maintaining and improving soil fertility levels. Studies have found that nitrate levels are markedly affected by residue decomposition which in turn is influenced by the amount of soil to straw contact (55,89,100). McCalla and Army (66) reported that the major chemical effect of tillage or lack of tillage was on total nitrogen levels. They indicated that researchers have found increased ammonia nitrogen on mulched soils when compared to plowed soils.

They also report that several studies noted depressed nitrate formation on mulched soils. McCalla observed that the time of field sampling for nitrates to be more critical than the nitrate differences at any particular time. Indications are that nitrate depression associated with stubble mulching undoubtedly accounts for some yield reduction noted in wet seasons; however, in dry years the benefits of stubble mulching usually outweigh the adverse effects of lower soil nitrogen.

2.7.2 Nitrate Levels with Minimum Tillage

Several early studies comparing chemical fallow to conventional tillage observed depressed nitrate nitrogen levels on untilled soils, but this deficiency was not generally reflected in yield (5,8,9,26,67, 74,96). Soils left untilled for extended periods of time may aggravate nitrate deficiencies and may require additional nitrogen fertilizer. This poses another problem for the no-tillage system as to a suitable method of fertilizer incorporation. The probable benefits from additional nitrogen response become obvious if chemical fallow results in greater moisture conservation (28,33,34,88).

Although several studies were conducted to evaluate the effects of mulching on other soil nutrient considerations, McCalla (66) indicated that nitrate status was the most important of these factors.

2.8 Other Considerations

2.8.1 Phytotoxicity from Surface Residues

Although the influence stubble mulching has on the number of soil microorganisms were found to be highly variable, toxicity problems may occur under certain situations. Observations from some studies indicated that phytotoxic substances produced during early stages of residue decomposition in soil may depress crop growth (66,76,77). This toxicity may retard germination or result in damage to seedling roots and increase susceptibility to soil-borne diseases. These problems may be intensified under no-tillage systems.

2.8.2 Insects and Plant Diseases

Despite mulches and untilled fields providing a more desirable environment for small organisms, few reports indicate problem situations with regard to insect infestation (66). Similarly, plant disease has been no more of a problem with stubble mulching than with plowing. Very little research has been conducted on these subjects with zero tillage systems.

2.8.3 Buildup of Chemical Residues

Although some research has indicated that residues from popular herbicides generally will not pose a serious toxicity problem, there is little information available regarding the implications of a long-term buildup of residues resulting from extensive herbicide use in no-tillage systems (40,68).

CHAPTER 3

DESIGN OF THE EXPERIMENT

3.1 Location of Study and Description of Soil

The study was initiated in 1967 at the Canada Agriculture Research Station, Lethbridge, Alberta. The general description of the soil is as follows:

	Silt Loam
Location	Lethbridge NE 4-9-21-W4
Soil Series	Lethbridge Silt Loam (Leth. SiL)
Classification	Orthic Dark Brown Chernozem
Parent Material	Alluvial lacustrine

3.2 Climate of the Area

3.2.1 General

The Rocky Mountains have a significant influence in moderating the extreme continental climate of the western plains. As a consequence of chinook winds, Lethbridge has the highest winter and annual mean temperatures on the prairies, and yet is slightly cooler than many southern prairie locations during the summer. Highly variable and unpredictable weather conditions of the area make it unwise to assume that average conditions will prevail at any specified time.

A comparatively long growing season, averaging 139 days, makes the area well suited for agriculture. Precipitation is usually favorably distributed for crop growth between April and August. Cultural operations usually commence in April and terminate as late as November.

3.2.2 Precipitation

Yearly precipitation at Lethbridge is highly variable and has ranged from 27.92 inches to 7.63 inches. The annual average of 16.18 inches is comprised from 10.84 inches of rain and 5.34 inches from snow. The greatest proportion of precipitation occurs during the months of May, June, July, August, and September amounting to 2.18, 3.06, 1.67, 1.53, and 1.64 inches respectively.

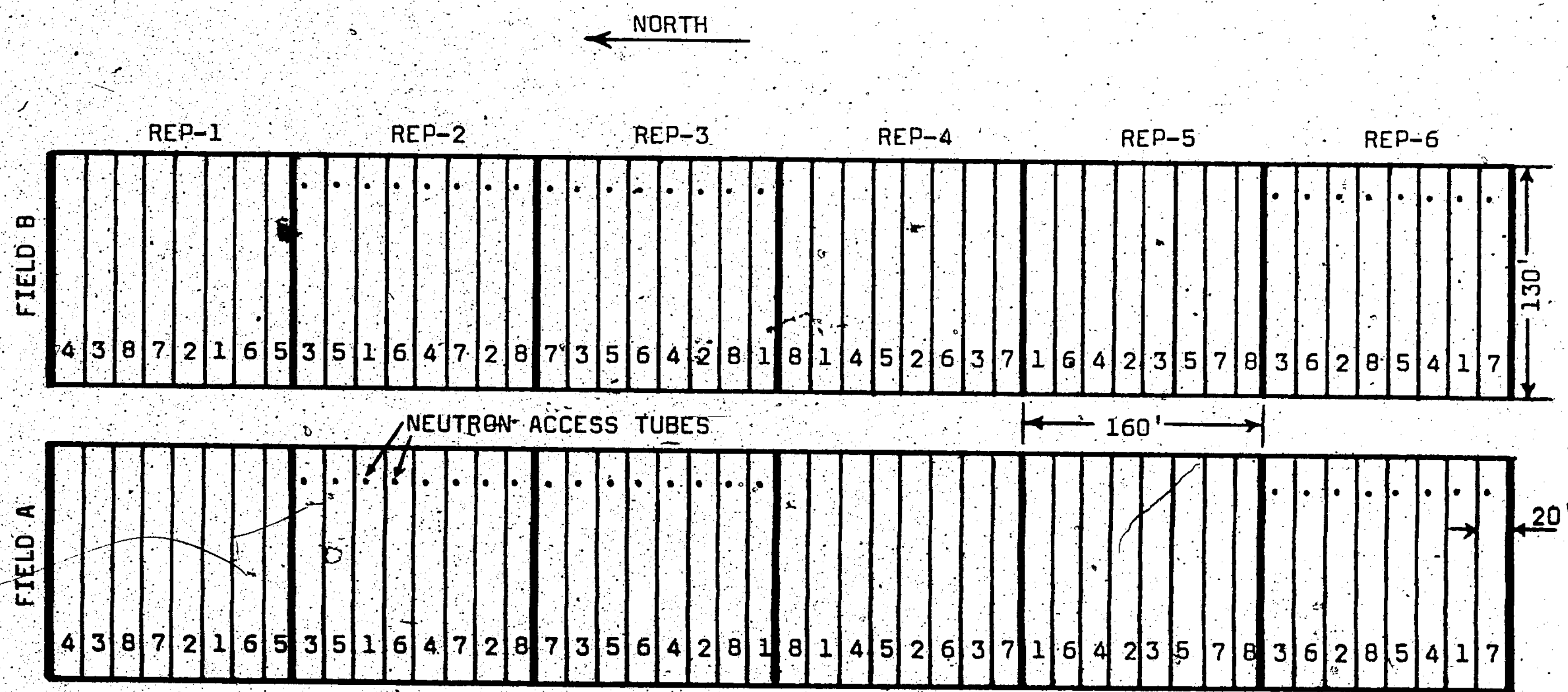
Distribution of snowfall is usually quite uniform throughout the winter months. Although snowfall averages 54 inches per year, it is unusual to have a snow buildup of more than 1 foot at any one time. Again, this is due to the moderating effect on winter temperatures of the chinook winds.

3.3 Field Layout

Two neighboring fields of approximately 3.5 acres each were set [illegible]or an alternating spring wheat-fallow rotation. Each field [illegible]ed into 48 plots comprised of a 6-replicate by 8-treatment [illegible]ed block layout with plots being 20 x 130 ft in size [illegible] 1).

[illegible] Summerfallow Treatments

The eight treatments (below) were selected to take advantage [illegible]ptimum use of herbicides and tillage throughout the fallow [illegible]son. Tillage was scheduled to occur at times when its value for weed control and/or soil amelioration for moisture conservation were optimum. Fall tillage, after harvest and at the end of summerfallowing, was designed to provide better moisture intake from



TREATMENTS

1. ONE-WAY DISC
2. CHEMICAL SEASON
3. BLADE, CHEMICAL
4. BLADE SEASON
5. FALL-BLADE, CHEMICAL
6. FALL-BLADE, CHEMICAL, FALL-BLADE
7. ONE-WAY SPRING, CHEMICAL
8. CHEMICAL, FALL-BLADE

Figure 1: Field plot layout and treatments.

snowmelt. The number of sweep-tillage operations with treatments involving chemical weed control was minimized to give upright orientation of residue. Fallow treatments involving discing were designed to effectively reduce large quantities of surface residue and possibly improve the soil nitrogen status.

Treatments:

1. One-way disc as required for weed control (May to September)
2. Chemical fallow, herbicides used when required for weed control
3. Blade in spring, herbicides remainder of season
4. Blade-cultivate as required for weed control (May to September)
5. Blade after harvest, herbicides for weed control (May to September)
6. Blade after harvest, herbicides (May to September), fall-blade
7. One-way disc in spring, herbicides remainder of season
8. Herbicides for weed control in spring and summer, fall-blade

3.5 Parameters Studied

1. A record was kept of weed growth, number of spray or tillage operations, and the weed control obtained.
2. Soil moisture was measured gravimetrically in each plot at 6-inch intervals to a depth of 5 feet in the fall and spring of each year of the wheat-fallow rotation.
3. Volumetric soil moisture (neutron) was measured to a depth of 5 feet at various times during fallow and crop seasons.
4. Crop residue was assessed for quantity and orientation after harvest and before preparing the seedbed.
5. Soil samples were taken to a depth of 2 feet prior to seeding to determine nitrate levels.

6. Records were kept of crop growth, mature plant height, and yield.

CHAPTER 4

EQUIPMENT

4.1 Tillage Machines

The main tillage implement used in the study was the wide-blade cultivator (V-type) (Figure 2). The blade is thought to be the best dryland tillage implement for maintaining optimum amounts of surface residue and providing effective weed control. Extensive studies have shown that the blade normally buries 10 to 15 percent of surface residue per operation (12,19,37).

The other summerfallow tillage implement utilized was the one-way disc (Figure 3). The one-way disc is an effective and economical method of weed control. However, studies indicate that each one-way disc operation buries about 50 percent of the surface residue; hence the number of operations for fallowing should be restricted (12,14,17,18).

The machine used for seedbed preparation was the heavy-duty cultivator equipped with a rod-weeder attachment. Studies have shown this implement to be very effective in weed control, residue conservation, and creating a desirable seedbed (12,16,37).

4.2 Seeding Machines

A double disc press drill (7 inch furrow spacing) was used to sow the spring wheat (Figure 4). Seed drills of this type have provided effective seed placement on fields having up to 2000 lb/ac of surface residue (10,17,37). It was considered that the press

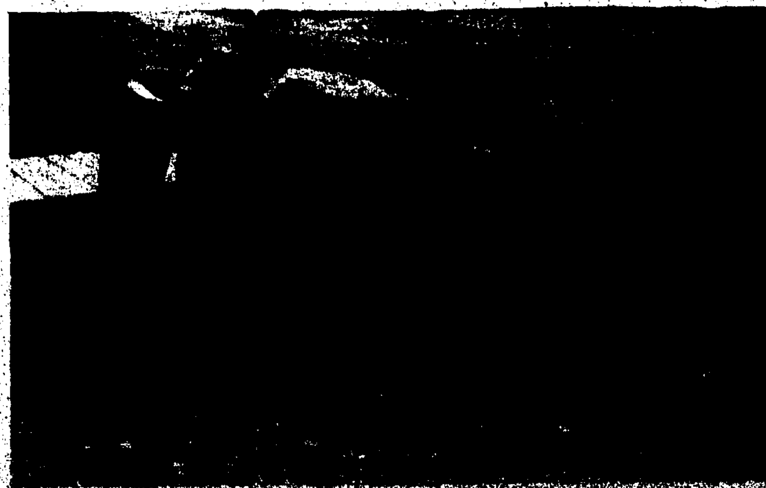
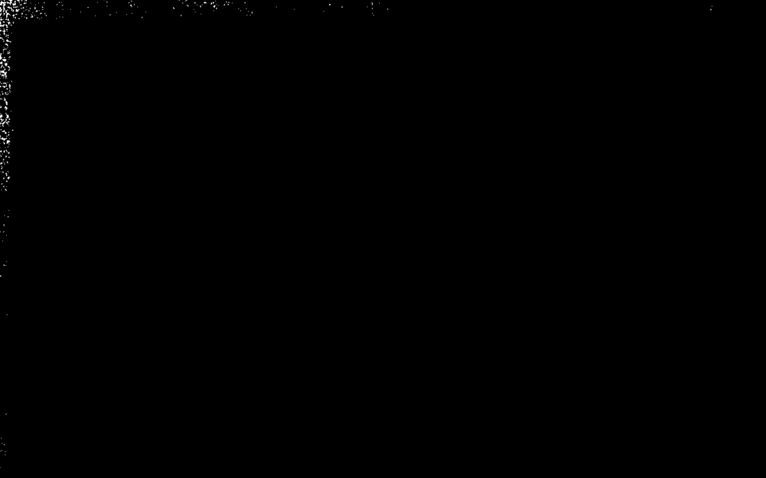


Figure 2: Wide-blade cultivator.

[illegible]



[illegible]

drill would minimize trash burial and the 7 inch spacing between furrows would permit easy windrowing of the mature crop.

4.3 Field Sprayer

Herbicides for weed control during fallow and crop seasons were applied with a field sprayer (Figure 5). The pivoting booms permitted easy small plot coverage. The rotary pump was powered by a 5 hp gasoline engine and provided water application rates of up to 50 gal/ac at 3 mph. The sprayer was equipped with various nozzle sizes to permit a wide range of application rates at a constant ground speed.

4.4 Harvesting Equipment

A 10 foot self-propelled swather or windrower normally was used to cut and windrow the mature crop (Figure 6). The ripe windrow was later thrashed using a self-propelled combine equipped with a pick-up attachment. In some years it was more convenient to straight combine the mature crop without windrowing. The combines were also equipped with paddle-type spreaders so as to provide a uniform distribution of unchopped straw.

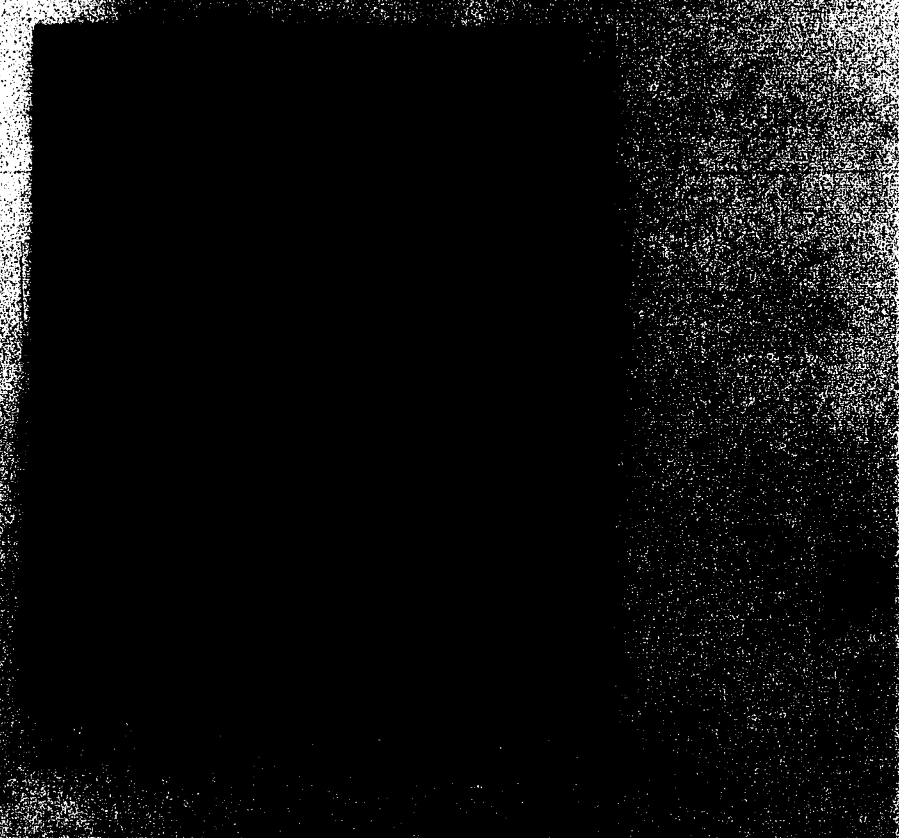
4.5 Soil Sampling Equipment

The majority of soil moisture samples were taken with a 5 foot 'King' tube. The tube had a replaceable tip that was tapered to prevent the soil core from falling out when the tube was removed from the soil. A specially designed, motorized derrick enabled the operator to easily hammer-in and remove the 'King' tube (Figure 7).

igure 5: Fiel[illegible]

[illegible]

Figure 7: Mo [illegible]



A graduated 'T' tube was used for smaller soil sampling jobs (Figure 8A). This tube permitted manual sampling to a depth of 24 inches; normally used for soil samples taken for chemical analysis. The soil samples taken with both the 'King' tube and 'T' tube were placed in relatively air tight cans (Figure 8B) to be taken to the laboratory for weighing and oven drying.

Soil moisture measurements were also made using a neutron moisture probe and scalar (Figure 9). This device has been found to be an easy and accurate method for measuring volumetric soil moisture (29,46). Access tubes (Figure 10) were installed near the east side of each plot in three of the replicates of each field (Figure 1). These access tubes, with removable upper extensions, were inserted to a depth of 54 inches. The extensions permitted the plots to be tilled without removing the entire tube. Moisture measurement was made by placing the probe shield on the protruding access tube and then lowering the probe to a desired depth. The probe contained a radioactive source (1 millicure Americium-beryllium) emitting fast neutrons and an electronic counter of slow neutrons which registered on the scalar during a 1 minute count. The count registered was proportional to the soil moisture content as predetermined by a calibration equation.

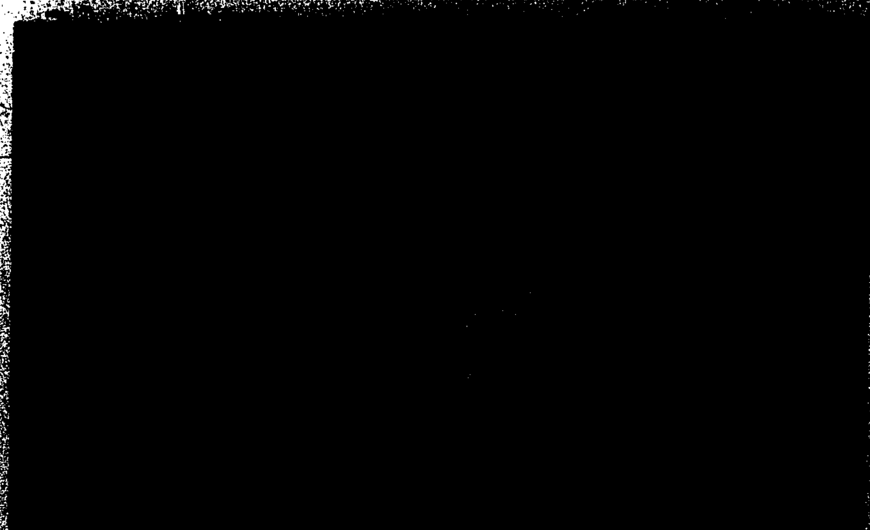


Figure 9: [illegible]

Figure 10: Extension [illegible]

CHAPTER 5

EXPERIMENTAL PROCEDURE

5.1 Application of Summerfallow Treatments

The fallow treatments previously described in section 3.4 were applied when their effectiveness was thought to be optimum. The species and degree of weed infestations dictated the application of tillage or herbicide treatment.

Sweep tillage was generally carried out when the soil was relatively dry, at a tilling depth of 3 to 4 inches and an operating speed of about 4 mph. The one-way disc was set at a tilling depth of about 4 inches and an operating speed of between 3 and 4 mph.

The herbicides used were limited to those not having a known residual carry-over effect on subsequent crops. The herbicide primarily used during the summerfallow season was paraquat; a non-selective, non-residual, and contact-type (as opposed to systemic--type) chemical which normally retarded plant growth at the application rates in this study. The usual rate of application was 12 to 16 oz of active acid in at least 25 gallons of water per acre. Several applications were generally necessary to maintain effective weed control. After-harvest, early spring, and fall sprayings utilized 2,4-D and similar herbicides. Depending on the type of weeds involved, the usual application rates of these herbicides were between 8 and 12 oz of active acid in 10 gallons of water. In some cases, more effective control of such 'hard-to-kill' weeds as wild buckwheat was attempted by combining 8 oz of bromoxynil plus MCPA ester in the paraquat and 2,4-D applications.

Records were kept noting weed varieties and effectiveness of control with the various summerfallow treatments. The number and timing of tillage and spray applications was also noted for each treatment.

5.2 Soil Moisture Sampling

Soil moisture samples were usually taken to a depth of 5 feet (4 feet prior to 1969) in 6 inch intervals from each plot in the fall and spring of each fallow and crop year. The samples were taken in the same region of each plot to maintain soil uniformity. The soil samples were then weighed, oven-dried (105° C), to a constant dry moisture content, and then reweighed to determine the soil moisture percentage on a dry weight basis.

$$\text{Percent Moisture} = \frac{\text{Wt. of wet soil} - \text{Wt. of dry soil}}{\text{Wt. of dry soil}} \times 100$$

Knowing the volume of the sample enabled easy calculation of apparent bulk density, thereby permitting percent moisture to be expressed in terms of volume percent or inches of water per unit depth.

$$\text{Bulk Density} = \frac{\text{Wt. of dry soil}}{\text{Vol. of soil}}$$

$$\text{Inches of water} = \%\ \text{moisture} \times \text{bulk density} \times \text{sample length (in.)}$$

5.3 Surface Residue Sampling

After harvest, 2 sq yd of surface residue were sampled at random on each plot of one replicate to determine the approximate quantity of stubble and straw at the beginning of the fallow cycle.

At the completion of the fallow cycle or just prior to preseeding tillage, all plots were again sampled (2 sq yd at random). All residue samples were segregated into loose and anchored classifications, permitting a more accurate assessment of the relative quantities conserved by the respective treatments. The samples were then weighed, washed and dried, then reweighed on an oven dry basis (60° C) to obtain a quantitative measure of crop residue.

5.4 Sampling and Determination of Nitrate Nitrogen

In three successive crop years, (1972-74) all plots were sampled for nitrate analysis just prior to preseeding tillage. Samples were taken at ten locations on each plot at depths 0-6, 6-12, and 12-24 inches. The ten samples from each depth were then combined and taken to the laboratory for analysis. The levels of nitrate nitrogen were determined by the standard method developed by Harper (56).

5.5 Seedbed Preparation and Seeding

In every year seedbeds were prepared with a heavy-duty cultivator equipped with a rod weeder attachment. Two operations in alternate directions across the plots were made to level dead furrows, maintain plot lines, and to unify conditions for good seed placement. Chinook spring wheat (Cypress variety in 1974) was usually sown the same day as preseeding tillage using a double-disc press drill.

5.6 Observations During Growing Season

Differences in crop germination were noted. Differential weed infestations were also recorded, and if warranted, herbicides such as 2,4-D were applied at recommended rates to all plots or sele[illegible]icates. When large infestations of wild oats were not[illegible]-emergence herbicides as Barban or Benzoylprop ethy[illegible]ed at recommended dosages. Differences in crop [illegible]tur[illegible] noted and a record was kept of the weed growth [illegible]rou[illegible] the crop year. Mature plant height measurements ([illegible] [illegible] were also taken on all plots prior to harvest.

[illegible] Soil Moisture Measurement During Crop and Fallow Seasons

Several measurements of soil moisture status were made du[illegible] the crop and fallow seasons with the neutron moisture probe des[illegible]ed in section 4.5. In 1972 neutron access tubes were installed [illegible]in three of the six replicates of each field (Figure 1). One-minute neutron counts were made with the probe centered at depths [illegible] 9, 12, 18, 24, 30, 36, 42, 48, and 54 inches; in effect measu[illegible]eres of volumetric soil moisture centered at these dept[illegible] A standard atmosphere count was also taken at each plot prior to the soil moisture count. The count ratio of soil moisture divided by the standard count was converted to percent moisture or inches of water by a calibration curve:

$$\frac{\text{Inches of water}}{\text{6 in. depth}} = 2.307 \text{ (count ratio)} + 0.0366$$

These moisture measurements were made during the crop and fallow seasons to determine any treatment differences with regard to moisture use and conservation. The readings were made during the fallow season to determine what effect, if any, that tillage or lack of tillage had in altering the soil moisture status. Moisture changes during the crop season were monitored to determine if any moisture differences at seeding were reflected in crop use as well as to determine if there were any treatment differences with respect to rate or efficiency of moisture use.

5.8 Harvesting

Usually the mature wheat crop was windrowed prior to threshing. The center 10 feet of each plot was swathed and later threshed as the yield sample for that plot. After the samples for yield were threshed, the whole field was harvested with a self-propelled combine equipped with a spreader so as to provide uniform straw distribution.

5.9 Soil Mechanical and Moisture Tension Analysis

Early in the study, soil samples were taken to a depth of 5 feet on several of the plots of each field to determine the soil texture classification. A standard hydrometer method of analysis was used (2) and a summary of the mechanical analysis is given in Appendix 1.

During the study, observations were made regarding localized soil textural differences which may have been biasing total moisture differences among treatments. For this reason, all plots were sampled to a depth of 5 feet and samples were taken to the laboratory for detailed moisture tension analyses (2). These analyses would enable a more accurate assessment of the available soil moisture status for a particular treatment.

5.10 Method of Analysis

Standard analysis of variance (111) was used to determine if treatment had a significant effect on the parameters of total available moisture, percentag e of precipitation conserved, soil moisture changes during fallow and crop seasons, surface residue quantities, nitrate nitrogen levels, mature plant heights, and crop yield (Table 1). Duncan's Multiple Range Test (111) was then utilized to determine exactly which of the treatments were significantly different from each other. All tests of statistical significance were performed at the five percent level unless otherwise stated.

Graphical analysis was used extensively to represent soil moisture status throughout the fallow cycles and also within the summerfallow and crop seasons. To maintain some degree of clarity, only four fallow treatments were represented on each graph.

A stepwise multiple regression analysis (102) was carried out on the yearly means from the 7 years data. The analysis included the independent variable of spring wheat yield. A standard t-test was applied to each of the coefficients of the independent variables to determine the significance of the factors in the explanation of yield variation.

TABLE 1: FORM OF ANALYSIS

	Source of Variance	Degrees of Freedom
AVAILABLE SPRING MOISTURE	Years	6
	Treatments	7
	Error	13
	Total	26
NEUTRON MOISTURE LEVELS	Replicates	2
	Treatments	7
	Error	9
	Total	18
PERCENTAGE PRECIPITATION CONSERVED	Cycles	4
	Treatments	7
	Error	11
	Total	22
NITRATE-N BY DEPTH AND TOTALS	Years	2
	Treatments	7
	Error	9
	Total	18
MATURE PLANT HEIGHTS	Years	6
	Treatments	7
	Error	13
	Total	26
CROP YIELD	Years	6
	Treatments	7
	Error	13
	Total	26

CHAPTER 6

RESULTS AND DISCUSSION

6.1 Precipitation During Study Period

Table 2 summarizes the seasonal precipitation data at the Research Station for the study period. Monthly and yearly precipitation during the study period was highly variable but generally well below normal when compared to long-term figures. The high variability made it difficult to compare any two years of the study period. For this reason, most of the subsequent discussion regarding moisture conservation will primarily consist of observations made on a year-by-year basis rather than attempting to generalize for the whole 7-year period.

A factor which may have partially compensated for the below average precipitation was the fact that mean monthly temperatures were also usually low during these dry periods. Weather records indicated that in many of the months receiving below average precipitation (particularly May and June) that mean monthly temperatures were also well below normal. This meant that evapotranspiration levels were lower, thereby reducing moisture stress on the growing crop. Factors such as this, plus the fact that the timeliness of precipitation was generally more important than the actual quantity, make it difficult to generalize about absolute quantities of precipitation.

6.2 Weed Control

The chief weed species encountered during the course of the

TABLE 2: SEASONAL PRECIPITATION DURING STUDY PERIOD AT RESEARCH STATION, LETHBRIDGE, ALBERTA (IN.)

Year	April	May	June	Jul	Aug	Sept	Yearly Total
1967	4.43	2.25	3.21	0.06	0.95	0.60	16.9
1968	1.59	1.69	2.76	0.72	1.94	3.84	15.6
1969	0.55	1.26	5.01	1.35	0.06	0.66	11.9
1970	1.19	1.29	3.41	0.63	0.59	1.50	12.9
1971	0.90	1.62	2.70	1.82	1.54	1.07	15.0
1972	0.94	1.10	1.64	2.10	0.31	1.39	13.4
1973	0.69	1.10	2.41	0.67	0.93	1.36	9.6
1974	3.54	1.78	0.60	1.08	2.09	0.59	13.05
Long term Average (1902-74)	1.26	2.12	3.00	1.64	1.50	1.61	15.95

study were flixweed, stinkweed, green foxtail, foxtail barley, wild buckwheat, downy brome, redroot pigweed, Russian thistle, prickly lettuce, volunteer wheat, and wild oats. The fallow treatments involving fall tillage after harvest (treatments 5 and 6) or fall application of 2,4-D ester (treatments 2 and 8) were very effective in controlling the winter annual weeds such as flixweed and stinkweed. Plots receiving the other fallow treatments required early tillage or herbicide applications the following spring to adequately control these weeds. The blade-only treatment (treatment 4) was not very effective in controlling flixweed, particularly if the weed was well advanced prior to the first tillage operation. Several spray applications of paraquat were usually necessary at three to four week intervals to adequately control the grassy weed varieties (foxtail barley, green foxtail, and wild oats) on those plots involving only chemical weed control during the fallow season (treatments 2, 5, 6, and 8). A summary of the fallow treatments and average number of tillage and spray applications for weed control is given in Table 3.

The one-way disc fallow (treatment 1) never required more than three operations to maintain good weed control. Fallow treatments involving tillage alone (treatments 1 and 4) were relatively ineffective methods of weed control when significant rainfall occurred soon after the tillage operation. Although rainfall subsequent to herbicide applications did not generally affect weed control, the weather conditions at the time of spraying were found to be critical. Effective weed control was not possible

TABLE 3: AVERAGE NUMBER OF TILLAGE AND SPRAY APPLICATIONS FOR EACH FALLOW TREATMENT (1968-74)

Treatment	Tillage	Spray
1. One-way disc	2.7	0
2. Chemical fallow	0	5.4
3. Spring-blade, chemical season	1.7	2.8
4. Blade season	4.0	0
5. Fall-blade, chemical season	1.0	5.0
6. Fall-blade, chemical season, fall-blade	2.0	5.0
7. One-way spring, chemical season	1.0	3.4
8. Chemical season, fall-blade	1.0	5.4

when herbicides were applied in winds greater than 15 mph. Better weed control was also noted when spraying was done under cool or cloudy conditions followed by a few days of sunny warm weather.

During the course of the study it was observed that certain species of weeds were more prevalent in some treatments than others. The perennial grassy type varieties seemed to predominate in the chemical plots and the broad leaf and winter annual varieties in the tillage plots. Although weed control was usually good with all treatments, there were isolated cases of advanced weed growth on particular treatments. Poor weed control seemed to be more evident with the blade fallow treatment (treatment 4) than with the other treatments.

6.3 Surface Residue Conservation

Fallow treatment, as was expected, had a significant effect on the quantity of crop residue remaining on the field surface at the completion of the fallow cycle. The mean quantities conserved with each fallow treatment are given in Table 4. A complete summary of data and analysis is given in Appendix 2. The fallow treatment involving only herbicides (treatment 2) conserved significantly more crop residue than all other treatments. Plots receiving herbicides with only one fall-blading (treatments 5 and 8) conserved more residue than those receiving more than one blading operation (treatments 3, 4, and 6). Although fallows receiving one or two bladings (treatments 3 and 6) conserved more residue than the blade-only fallow (averaging 4 bladings), the differences were not significant. Fallow treatments involving the one-way

TABLE 4: MEAN QUANTITIES OF SURFACE RESIDUE ON PLOTS PRIOR TO SEEDBED PREPARATION (1969-74)

Treatment	Loose Residue (lb/ac)	Anchored Residue (lb/ac)	Total (lb/ac)
1. One-way disc	178[a]	7[a]	185[a]
2. Chemical fallow	2430[de]	414[c]	2844[f]
3. Spring-blade, chemical season	1710[c]	169[ab]	1879[cd]
4. Blade season	1576[c]	70[ab]	1646[c]
5. Fall-blade, chemical season	2178[d]	178[b]	2356[e]
6. Fall-blade, chemical season, fall-blade	1759[c]	90[ab]	1849[cd]
7. One-way spring, chemical season	828[b]	49[ab]	877[b]
8. Chemical season, fall-blade	1958[cd]	116[ab]	2074[de]

a,b,c,d,e,f, Column means with a common letter in the superscript are not significantly different at the 5 percent probability level.

disc (treatments 1 and 7) conserved significantly less residue than the other treatments.

Only fallow treatments involving little or no tillage (treatments 2, 3, 5, and 8) were effective in conserving substantial quantities of upright residue. Fallows receiving no tillage (treatment 2) maintained significantly more anchored or upright residue than all other fallows. Treatments involving the one-way disc (treatments 1 and 7) conserved very little anchored residue. An important consideration was also the fact that normal weathering and chemical breakdown of surface residue was a major contributor to the residue reduction process during the fallow cycle.

6.4 Soil Moisture Conservation

6.4.1 Gravimetric Measurements

Mechanical analysis of soil cores taken from each plot indicated some degree of textural differences according to fallow treatment despite the randomized plot layout. A summary of this data in terms of the mean moisture holding capacities for the various treatments is given in Table 5. A more detailed summary is given in Appendix 3. Because of these apparent soil differences, all soil moisture data in the subsequent discussion will be expressed in terms of available inches of water in the 4 or 5 foot soil profile. Usually, the spring wheat crop did not utilize soil moisture below a 4 foot depth; however, during a few years there may have been some moisture uptake from below this depth. For this reason, soil moisture samples were taken to a depth of 5 feet after the first

TABLE 5: THEORETICAL FIELD CAPACITY (1/3 ATM) AND WILTING POINT (15 ATM) DETERMINED FROM SOIL MOISTURE TENSION ANALYSIS TO A 5 FOOT DEPTH (INCHES OF WATER)

Treatment	Field A		Field B	
	1/3 atm	15 atm	1/3 atm	15 atm
1. One-way disc	15.73^{a}	7.01^{ab}	15.26	7.01^{bc}
2. Chemical fallow	15.65^{a}	6.86^{ab}	14.39	6.29^{a}
3. Spring-blade, chemical season	16.03^{ab}	7.05^{ab}	14.81	6.44^{ab}
4. Blade season	14.82^{a}	6.66^{a}	15.50	7.15^{c}
5. Fall-blade, chemical season	15.42^{a}	6.91^{ab}	14.83	6.82^{abc}
6. Fall-blade, chemical season, fall-blade	15.13^{a}	6.61^{a}	15.78	7.00^{bc}
7. One-way spring, chemical season	17.34^{b}	7.51^{b}	15.38	7.17^{c}
8. Chemical season, fall-blade	17.34^{b}	7.53^{b}	14.58	6.62^{abc}
			D.N.S.	

a,b,c Column means with a common letter in the superscript are not significantly different at the 5 percent probability level.

D.N.S. Differences not significant at the 5 percent probability level.

two years of the study.

Table 6 lists the mean available spring moisture levels obtained with each fallow treatment. A more detailed summary and analysis is given in Appendices 4 and 5. Chemical fallow (treatment 2) had significantly more available moisture in the spring than all other treatments with the exception of treatment 3. Plots involving only mechanical tillage (treatments 1 and 4) had the least available soil moisture and averaged nearly 1 inch less than the chemical fallow plots. The same relationship existed between both the 7-year means to 4 feet and the 5-year means to 5 feet.

Although the available soil moisture status is most important in the spring of the crop year, it is interesting and also of some importance to know the moisture status at various times throughout the 20-month fallow period. The subsequent graphs and discussion will summarize the changing soil moisture status during the five fallow periods of this study. The graphical representation is based on gravimetric soil moisture data from samples taken in the spring and fall of each year and then converted to available soil moisture.

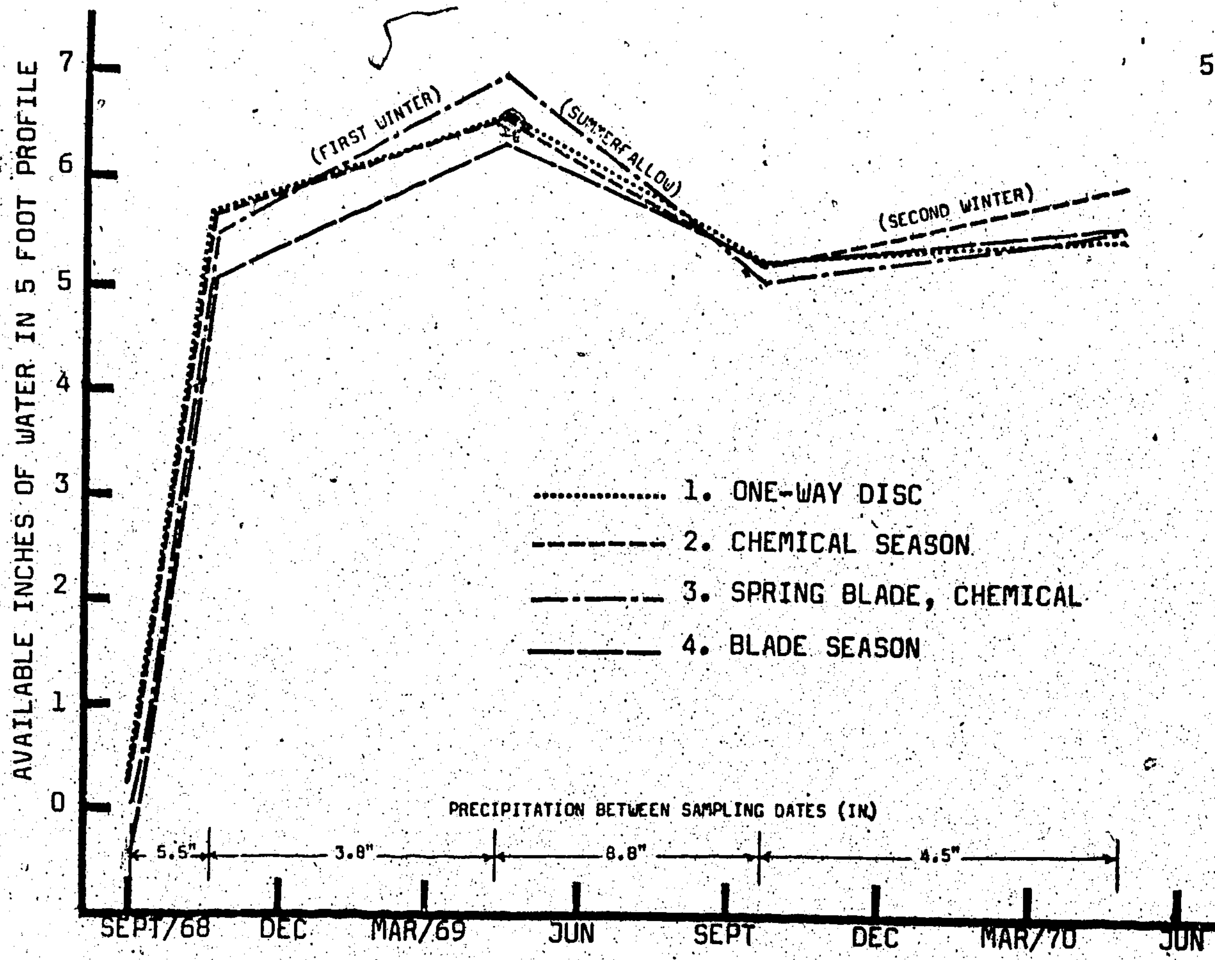
A. <u>1968-70 Fallow Cycle</u>

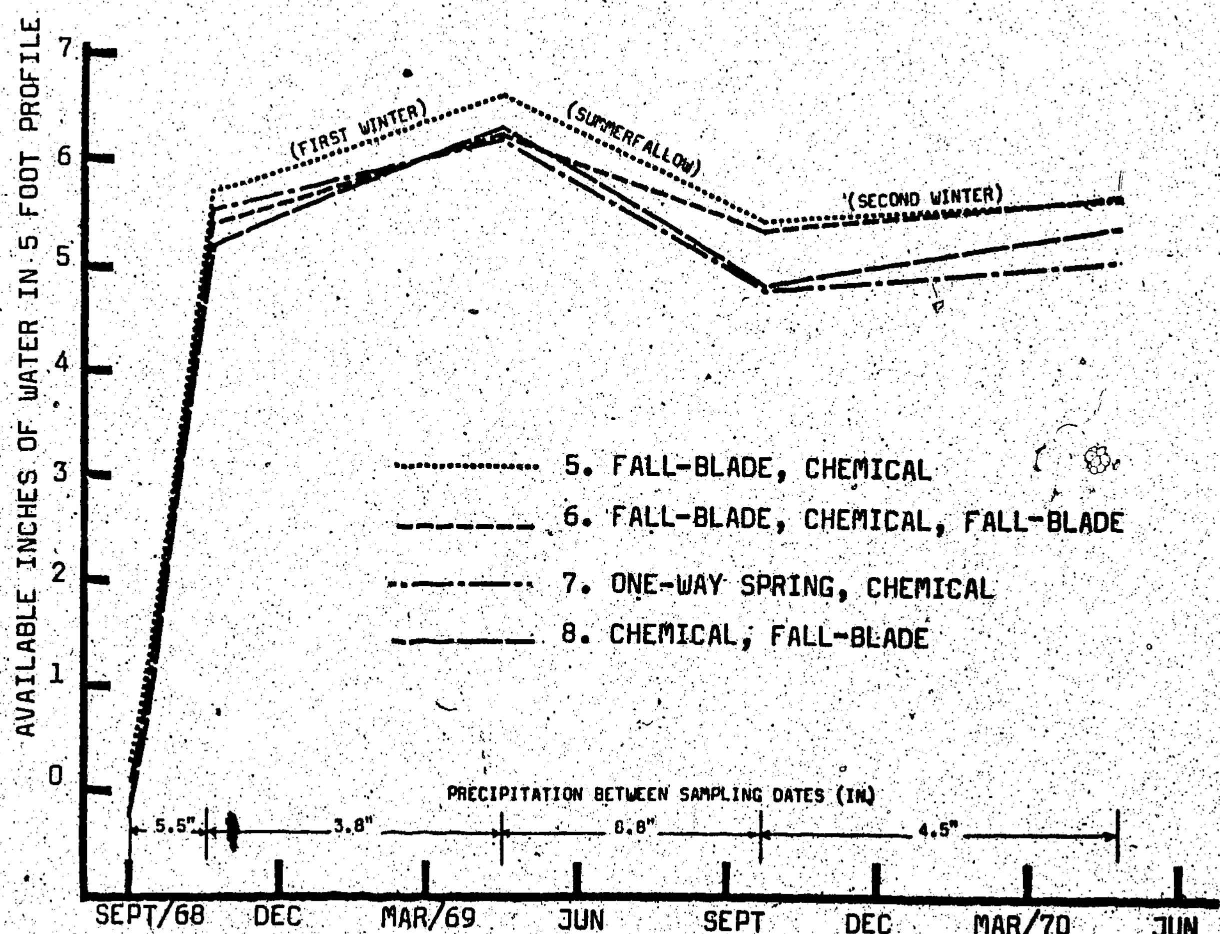
Figure 11 illustrates the effects that an unusually wet fall after harvest had on the soil moisture status during the 1968-70 fallow period. Initially, all of the available moisture had been utilized, and the 5 foot soil profiles of all treatments were relatively dry. However, heavy snows and rainfall occurring late in September and early October resulted in moisture gains

TABLE 6: MEAN AVAILABLE MOISTURE STATUS IN SPRING OF CROP YEAR (GRAVIMETRIC).

Treatment	Available Moisture (in.) to 4 Foot Depth (1968-74)	Available Moisture (in.) to 5 Foot Depth (1969-74)
1. One-way disc	4.38^{a}	5.04^{a}
2. Chemical fallow	5.30^{c}	6.22^{d}
3. Spring-blade, chemical season	4.94^{bc}	5.88^{cd}
4. Blade season	4.36^{a}	4.95^{a}
5. Fall-blade, chemical season	4.73^{ab}	5.48^{abc}
6. Fall-blade, chemical season, fall-blade	4.75^{ab}	5.70^{bc}
7. One-way spring, chemical season	4.66^{ab}	5.44^{abc}
8. Chemical season, fall-blade	4.64^{ab}	5.30^{ab}

a,b,c,d Means with a common letter in the superscript are not significantly different at the 5 percent probability level.





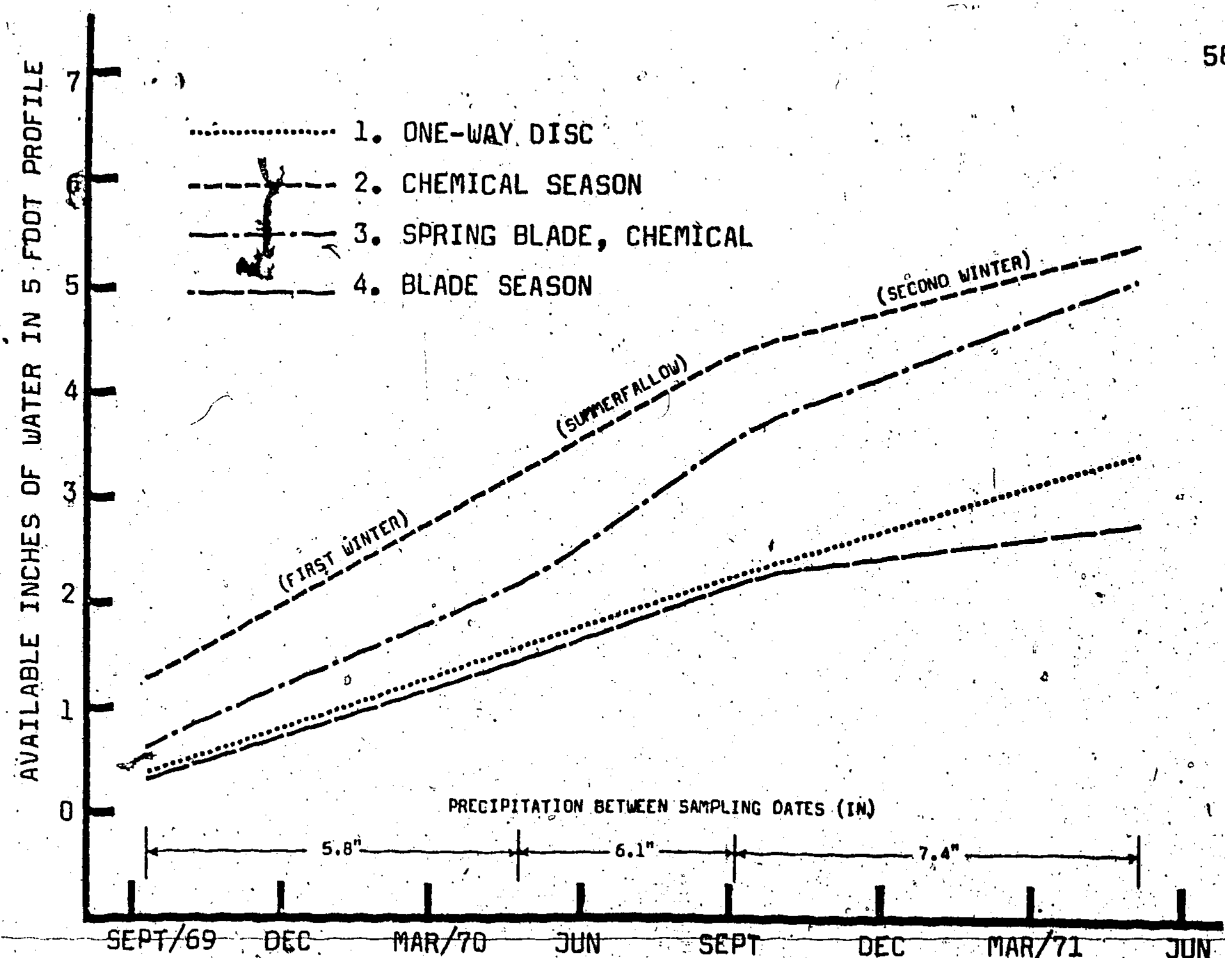
Fig[illegible]il moisture status during 1968-70 fallow cycle (field A).

nearly equivalent to the precipitation received. Soil moisture differences were not significant as only two fallows (treatments 5 and 6) had received any tillage by this moisture sampling date (Oct. 16). All fallows gained additional moisture during or soon after the first winter period. Although differential moisture gains between treatments were not significant, they appeared to be inversely related to the total moisture status before freeze-up. The two fallows involving fall-blading (treatments 5 and 6) gained slightly less moisture during the first winter than did most of the other fallow treatments. Despite above average precipitation, all plots lost between 1 and 2 inches of soil moisture during the summerfallow season. The soil profiles containing the most moisture in the spring generally lost the most moisture during the summerfallow season. Fallow treatment had little effect on minimizing these losses. However, those plots that received a blading in the previous fall (treatments 5 and 6) lost less moisture than the other fallows, possibly due to better weed control. Although gains were slight, the moisture status on all plots improved during or soon after the second winter period. Overall, fallow treatment had no significant effect on moisture conservation for this particular fallow cycle.

A significant point to be made regarding this fallow cycle was that the soil moisture status after the first winter was substantially better than that after the second winter on all plots. In cases such as this, it would be impossible to justify summerfallow on the basis of moisture conservation alone.

B. 1969-71 Fallow Cycle

The next fallow cycle of 1969-71 (Figure 12) was somewhat more typical than the previous cycle with regard to precipitation distribution throughout the 20-month fallow period. Initially, the chemical fallow plots (treatment 2) had slightly more available moisture (0.3 to 1.0 inches more) than the other plots, primarily concentrated in the 4 to 5 foot zone. Since no precipitation had occurred between harvest and moisture sampling, this may have been due to inability of the crop to fully utilize the excess water stored at this depth. All plots showed moisture gains of at least 1 inch after the first winter period. Despite having more moisture initially, the chemical fallow gained the most moisture (2 inches) of any fallow treatment. The fall-blading (treatments 5 and 6) seemed to have very little influence in improving moisture intake from snowmelt, although fallow treatment 6 ranked second in both moisture gained and total available moisture. The chemical fallow again had significantly more moisture after the summerfallow season in spite of other fallows (treatments 3 and 8) gaining more moisture. The fallows involving only mechanical tillage (treatments 1 and 4) had significantly less available moisture (1.3 to 2.6 inches less) than the other fallow treatments. This was attributed to greater evaporation and possibly less than optimum weed control during the summerfallow season. The poorer moisture status of these fallows was not improved during the second winter period. The one-way and blade fallows had by far the least available moisture of any treatment prior to seeding. Fallows receiving



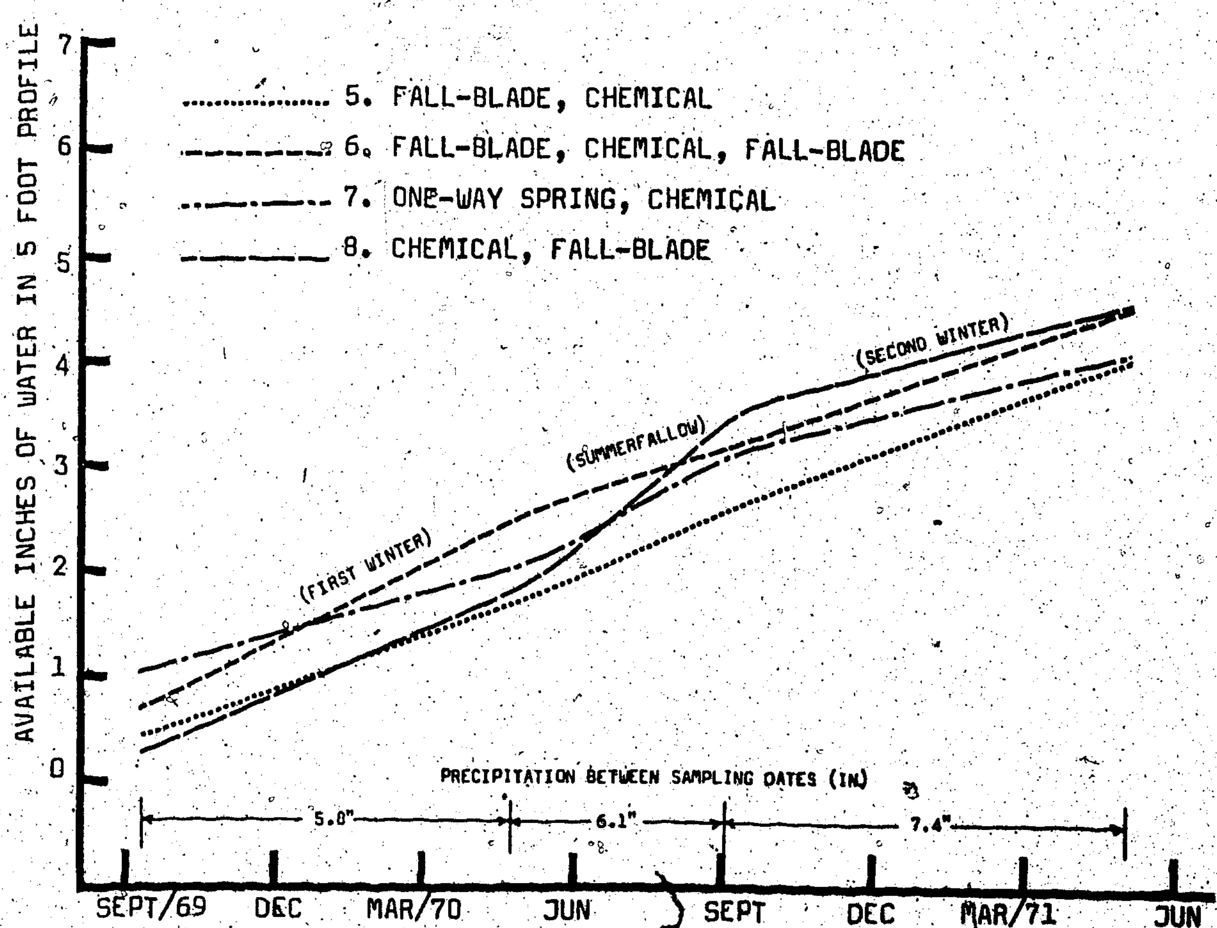
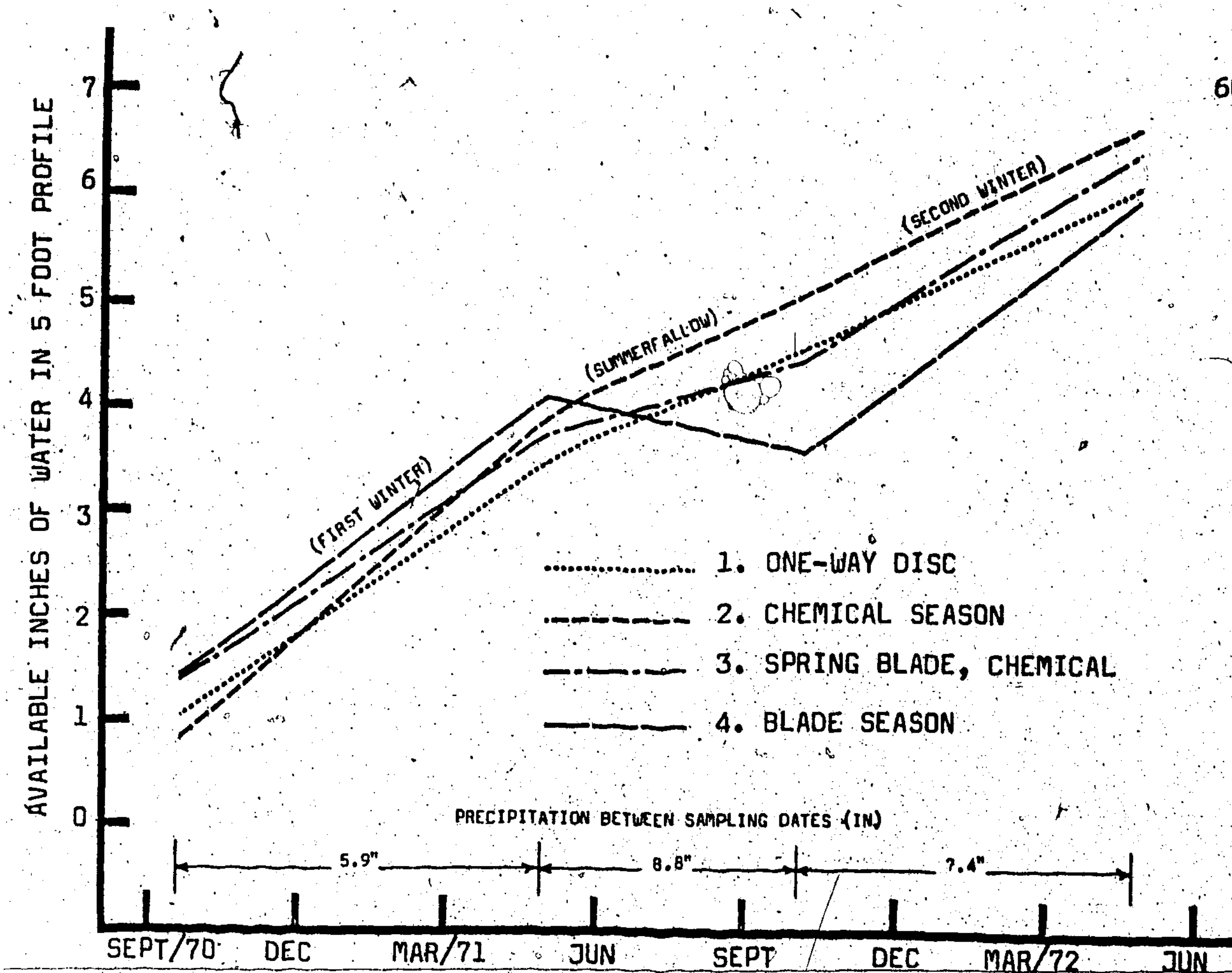


Figure 12: Soil moisture status during 1969–71 fallow cycle (field B).

little or no tillage maintained the most soil moisture throughout the fallow cycle.

C. 1970-72 Fallow Cycle

Initially, in the third fallow cycle (Figure 13), all plots contained between 1 and 1.5 inches of available water, reflecting the 1.5 inches of rainfall which occurred since harvest. Most plots conserved a significant portion (40 to 60 percent) of first winter precipitation. However, the two fallows receiving fall-blading (treatments 5 and 6) gained significantly less moisture (0.9 to 1.6 inches less) than the other fallow treatments. On the other hand, the fallows receiving these two treatments conserved the most moisture during the summerfallow period, probably due to the dry soil profile being more susceptible to moisture gain plus better-than-average weed control. The blade fallow (treatment 4), in fact, lost moisture (0.5 inches) during the summerfallow season, thought to be largely due to inadequate weed control and evaporation losses with the coarse surface mulch. The blade fallow markedly improved its moisture status by gaining at least 0.5 inches more moisture during the second winter period than any other treatment. The fallows receiving a blading operation in the second fall (treatments 6 and 8) conserved significantly less moisture from second winter precipitation than most of the other fallow treatments. The chemical fallow plots (treatment 2) again maintained the best moisture status throughout the fallow cycle, but moisture differences were not significant at the end of the fallow period.



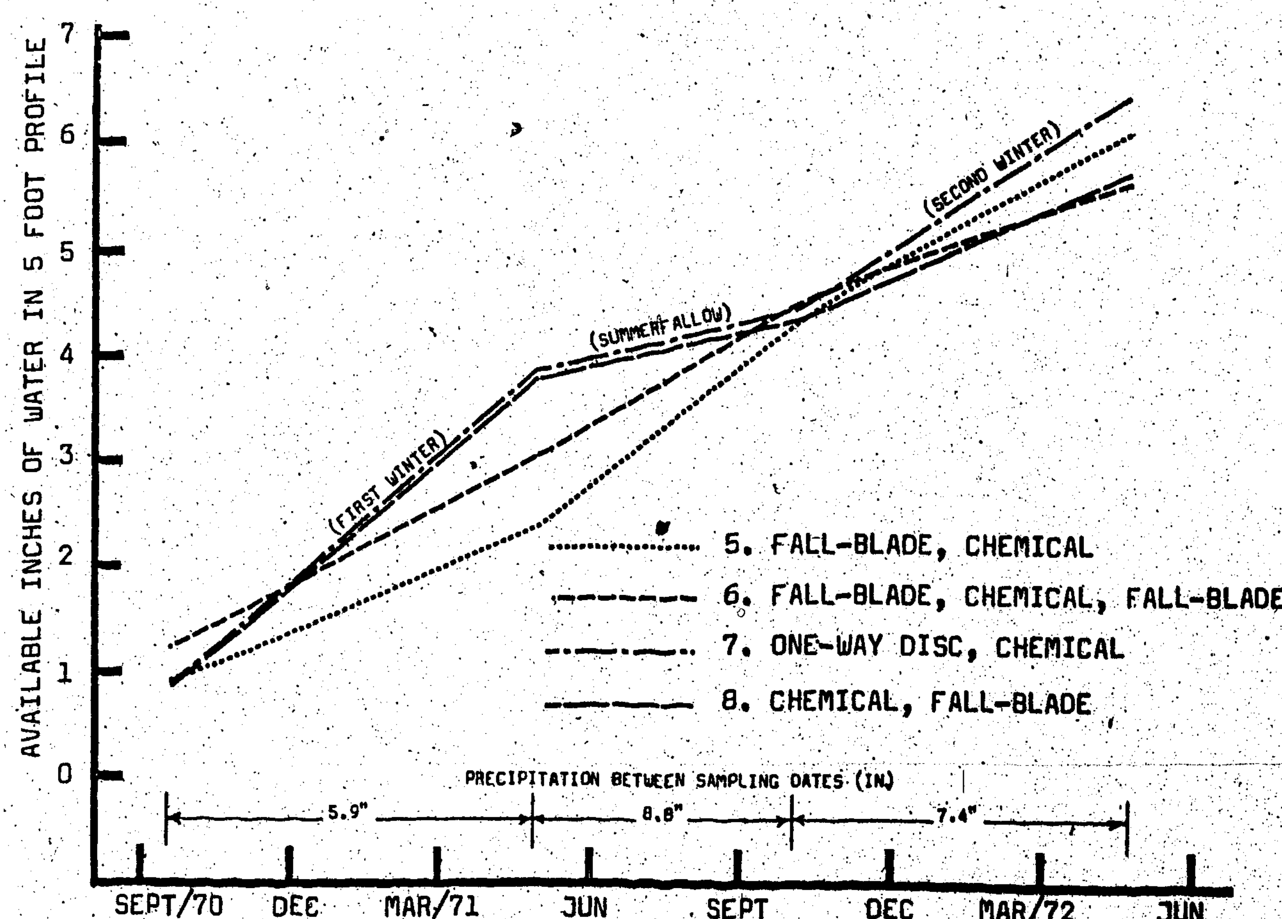


Figure 13: Soil moisture status during 1970-72 fallow cycle (field A).

D. 1971-73 Fallow Cycle

Soil moisture samples taken in the fall of 1971 (Figure 14) showed that the crop had fully utilized available moisture to a depth of 5 feet. This also illustrates that a crop may extract soil moisture held at a greater negative tension than 15 atmospheres (the theoretical wilting point used in this study).

Initially, there were no significant moisture differences for the 1971-73 fallow cycle. All plots conserved at least 40 percent of first winter precipitation with the chemical fallow (treatment 2) conserving significantly more moisture (0.6 to 1.3 inches more) than all other treatments. Moisture gains during the relatively dry summerfallow season were minimal and generally inversely related to the total moisture status in the spring. Similarly, moisture conservation during the second winter period was low (less than 1.5 inches) for all fallows and moisture gains were inversely related to corresponding summerfallow gains. Again, the chemical fallow (treatment 2) conserved the most and had significantly more available moisture (0.9 to 2.6 inches more) at the end of the fallow cycle than any other treatment. Also, the fallows receiving only one-way and blade tillage (treatments 1 and 4) had significantly less available moisture (1.16 to 2.6 inches less) than all other treatments.

E. 1972-74 Fallow Cycle

The 1972-74 fallow cycle (Figure 15) also began with all plots essentially at or below the theoretical wilting point. Initially, two fallows (treatments 7 and 8) contained somewhat less moisture, though not significantly less, than the other fallow

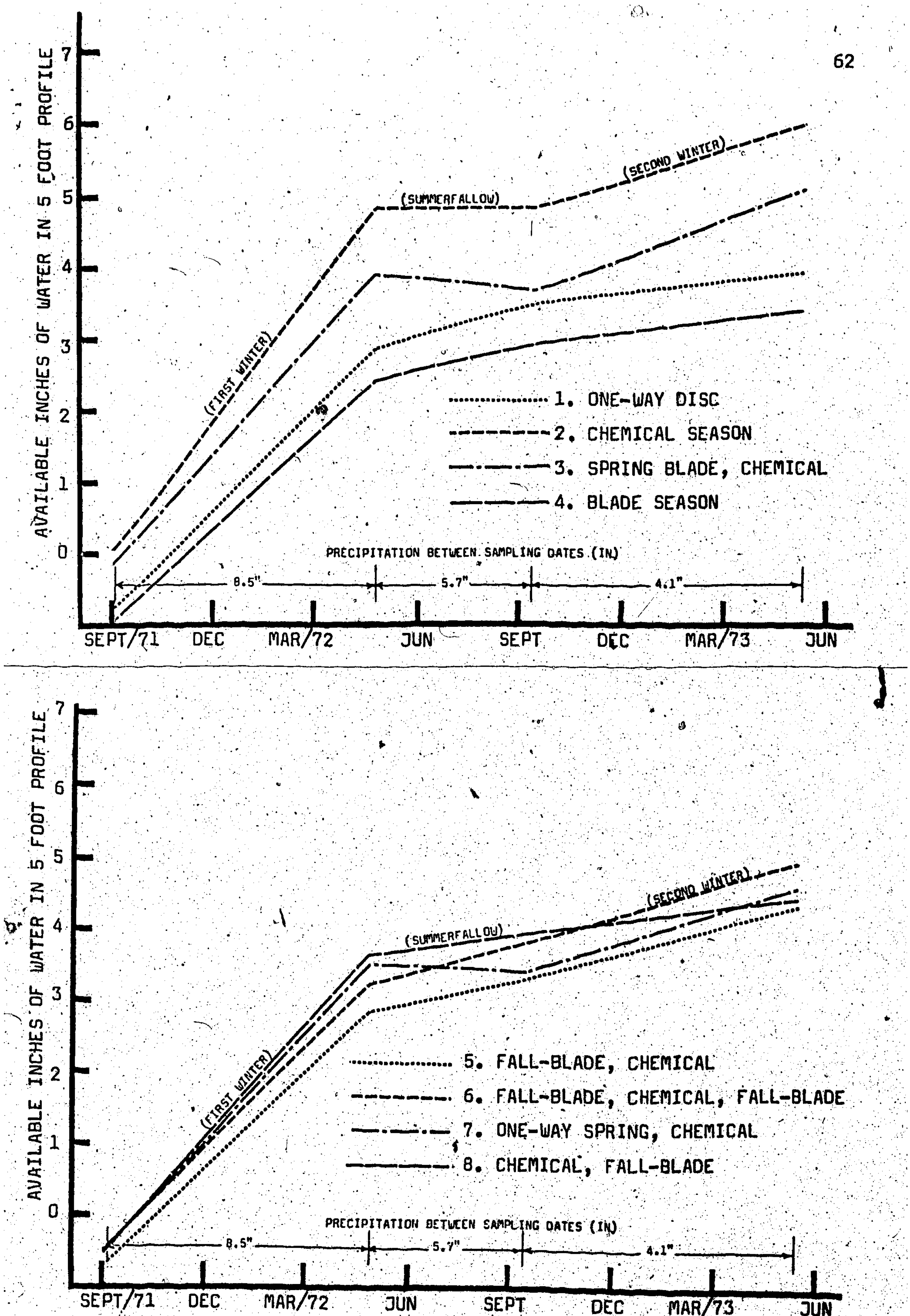
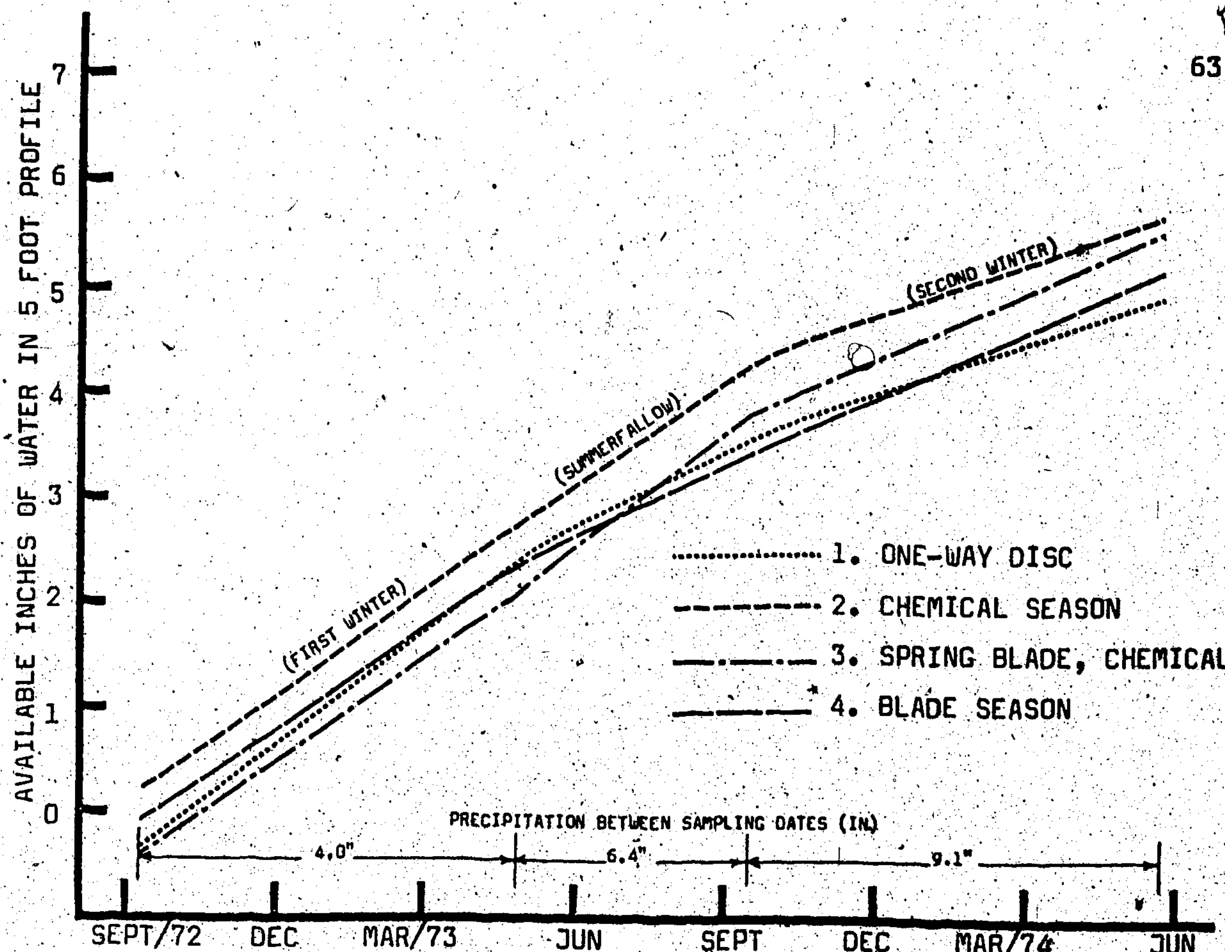


Figure 14: Soil moisture status during 1971-73 fallow cycle (field 8).



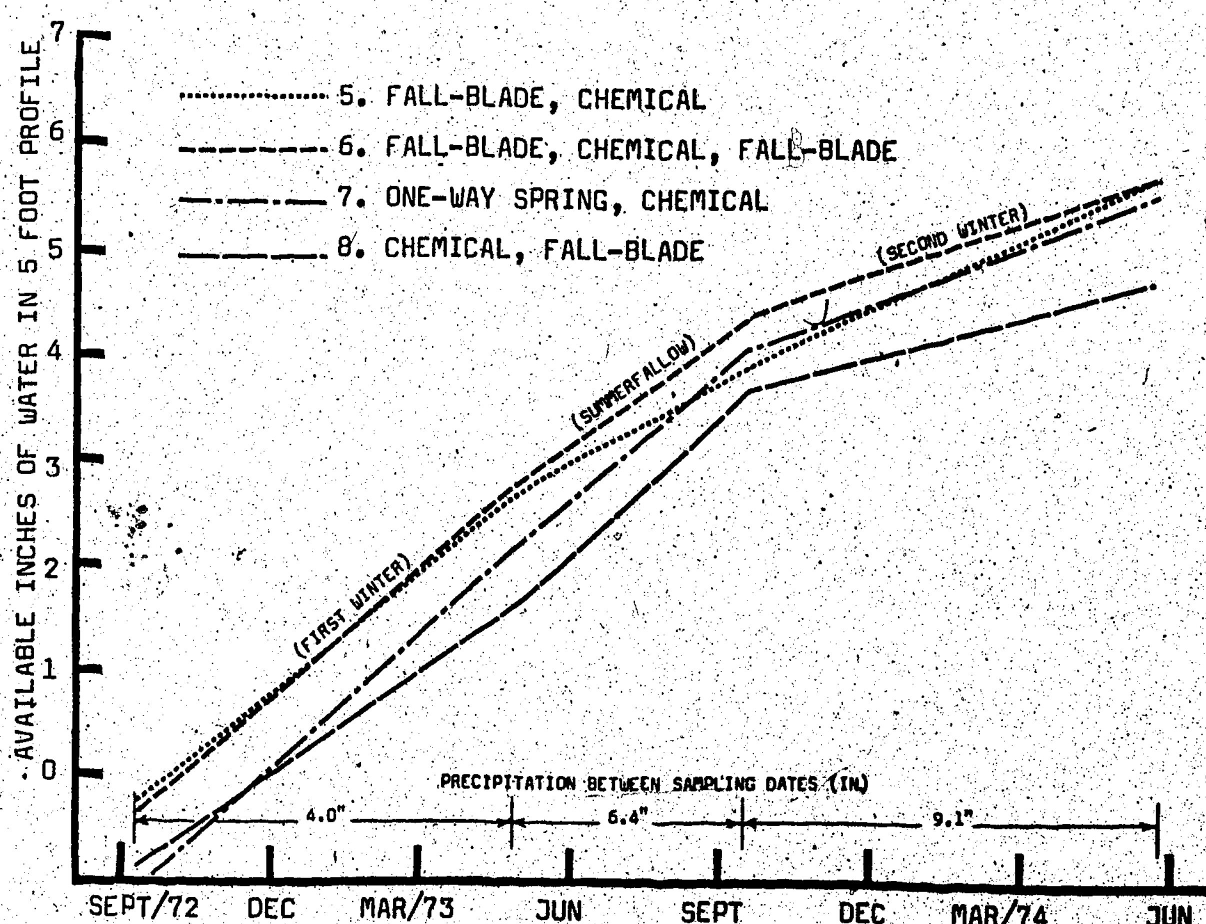


Figure 15: Soil moisture status during 1972-74 fallow cycle (field A).

plots. All fallows conserved between 2.5 and 3.5 inches of the 4 inches of precipitation which occurred during the first winter period; the drier soil profiles gaining the most moisture. Although the differences were not significant, the fallows receiving a fall-blading (treatments 5 and 6) conserved more-than-average, and had the most soil moisture after the first winter. All plots gained between 1 and 2 inches of moisture during the summerfallow season, with the two driest fallows (treatment 7 and 8) gaining the most and the mechanically tilled fallows (treatments 1 and 4) gaining the least. Moisture gains during the second winter were similar with all fallows and generally inversely related to moisture status prior to freeze-up. However, worthy of noting is the fact that the fallow receiving a fall-blading (treatment 8) conserved less moisture (at least 0.5 inches less) than any other fallow. Overall, this fallow (treatment 8) had significantly less available moisture (nearly 1 inch less) in the 5 foot profile than most of the other fallow treatments (treatments 2, 3, 5, 6, and 7). The fallows receiving only mechanical tillage (treatments 1 and 4) conserved the least moisture overall of any fallow treatment.

A summary of the five fallow cycles in terms of mean percentages of precipitation conserved over each interval of the fallow period is given in Table 7. A complete summary on a yearly basis for each fallow cycle is given in Appendix 6. The high variability between years partially accounts for the fact that treatment differences were not statistically significant for any interval of the fallow cycle.

TABLE 7: MEAN PERCENTAGES OF PRECIPITATION CONSERVED IN 5 FOOT SOIL PROFILE THROUGHOUT THE FALLOW CYCLE (1968-74)

Interval	Fallow Treatment								Ave. Precipitation for Interval (in.)
	1	2	3	4	5	6	7	8	
First Winter	45.0	51.8	47.6	44.0	43.5	47.4	49.3	48.3	7.2
Summerfallow	7.4	8.3	6.2	3.9	11.8	12.8	13.6	9.0	7.1
Second Winter	13.1	19.0	22.3	15.3	18.8	16.6	18.3	14.0	6.5
Overall	21.8	25.7	24.9	21.1	24.0	24.3	24.2	24.0	20.8

Although the differences were not significant, the chemical fallow (treatment 2) conserved more moisture from precipitation during each interval of the fallow cycle than any other fallow treatment. Overall, the fallows involving only mechanical tillage (treatments 1 and 4) conserved less moisture than the other treatments. The treatment differences after the first winter period, though not significant, possibly indicated some carry-over effect from the previous year's fallow treatment. The fallows receiving a fall-blading (treatments 5 and 6) did not conserve any more (and usually less) moisture during the first winter period than the other treatments. However, these treatments, along with treatment 7, seemed to be particularly effective in conserving more seasonal precipitation during the summerfallow period, probably due to better weed control. Poorer weed control on the bladed fallow (treatment 4) was thought to be the reason for particularly poor moisture conservation (only 3.9 percent) during the summerfallow season, although conservation differences were not significant. Fall-blading prior to the second winter (treatment 8) did not seem to improve moisture conservation during that period. Interesting to note is the fact that the fallows from all treatments combined conserved twice as much moisture during the second winter period than they did during the summerfallow period, in spite of receiving less precipitation.

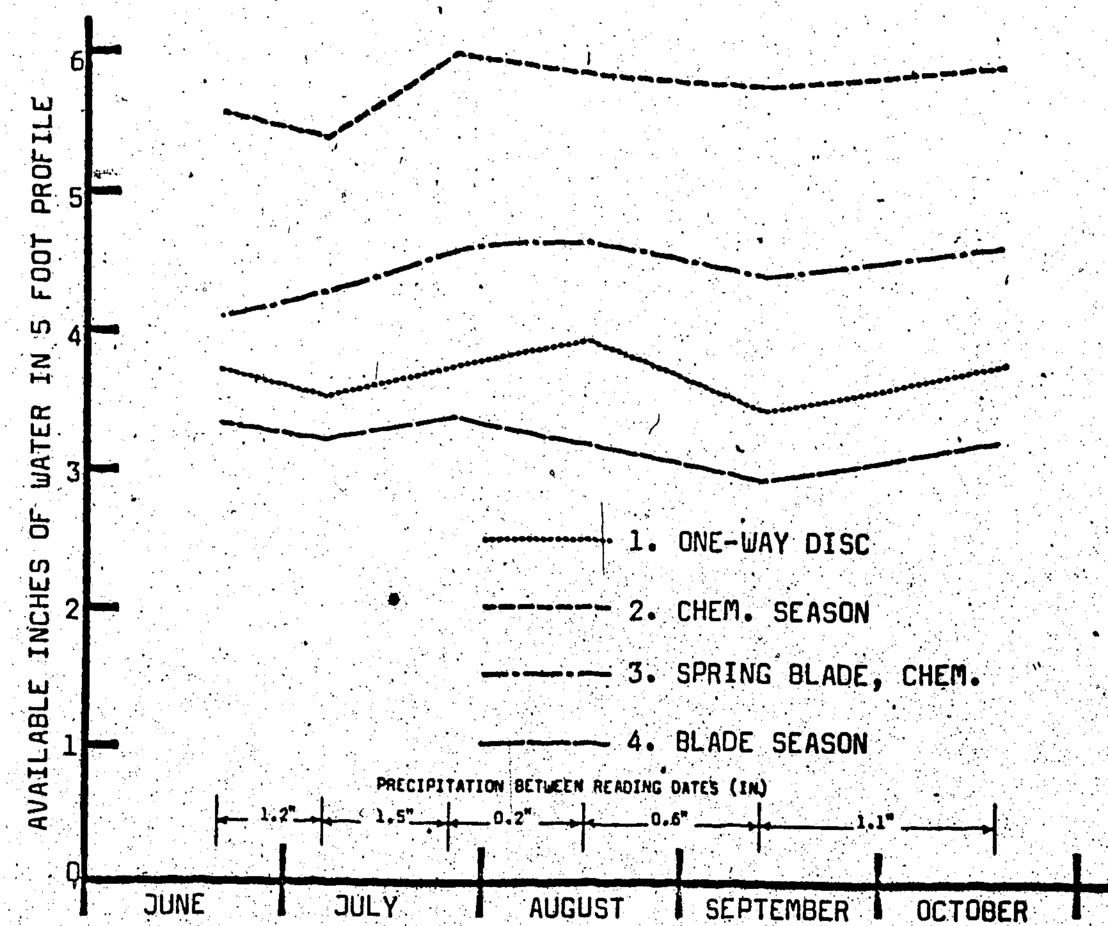
6.4.2 Neutron Moisture Readings

As previously mentioned, access tubes were installed in three replicates of each field permitting neutron moisture readings at various intervals throughout the fallow and crop seasons. These periodic readings throughout the fallow season enabled a more accurate assessment as to the effects that tillage treatment had on moisture conservation. Moisture readings taken during the crop year indicated the effects of fallow treatment on the efficiency of moisture use by the crop.

Analysis of variance was carried out on moisture differences for each date as well as moisture changes between dates; however, because of the great quantity of data and analyses involved, the moisture data will be expressed in graphical form for the subsequent discussion. A more detailed summary and analysis may be found in tabular form in Appendix 7.

A. 1972 Summerfallow Season

The available moisture status throughout the summerfallow season of 1972 (field B) is shown in Figure 16. Initially, the chemical fallow (treatment 2) had significantly more available moisture (1.9 to 2.3 inches more) than treatments 1, 4, and 5. The chemical fallow maintained this significant moisture advantage throughout the summerfallow season. Moisture differences in the fallows of the other treatments were not significant throughout the season. Although there were no significant treatment differences with regard to moisture gains between reading dates, the fallows receiving a blading the previous fall (treatments 5 and 6) showed the greatest moisture gains of any fallow treatment. The relatively poor moisture status with plots involving only mechanical tillage



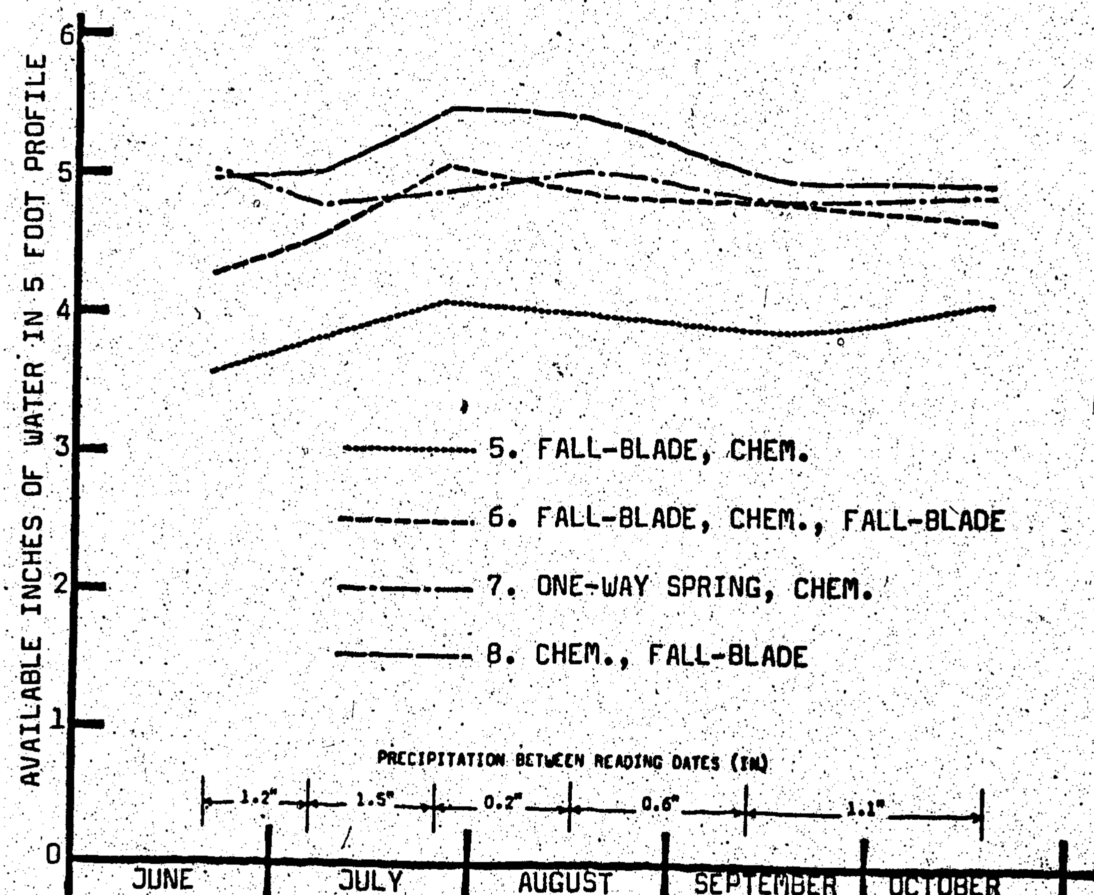


Figure 16: Soil moisture status during 1972 summerfallow season (field B).

(treatment 1 and 4) did not improve by the end of the summerfallow season. Although adequate weed control was more difficult on the bladed plots, this was not considered to be the only factor contributing to the poor moisture status. Weed control was considered to be very good on the one-way disc fallow (treatment 1), yet the total available moisture status was not improved by the end of the summerfallow period.

B. 1972 Crop Season

The initial neutron moisture readings were not taken until about 4 weeks after seeding in the 1972 crop year (field A). Figure 17 represents the soil moisture status for each fallow treatment at various stages throughout the growing season. Differences in available moisture were not significant on the first reading date (June 13). At this time the crop had utilized very little reserve moisture as a result of the 1.6 inches of precipitation since seeding. By the second reading date (July 13) the crop was fully in head and about one-half of the reserve soil moisture had already been utilized. Although available moisture differences were not significant on the second date, the moisture changes between dates were significantly different. Crops growing on fallow treatments 3 and 4 used less reserve moisture (0.2 to 0.5 inches less) than did the crops on other fallow treatments. Soil moisture depletion (about 1 inch) was similar for all plots between the second and third reading date (August 1). However, during August and prior to harvest (August 28), moisture depletion from some plots (treatments 6 and 8) was significantly less than from most other

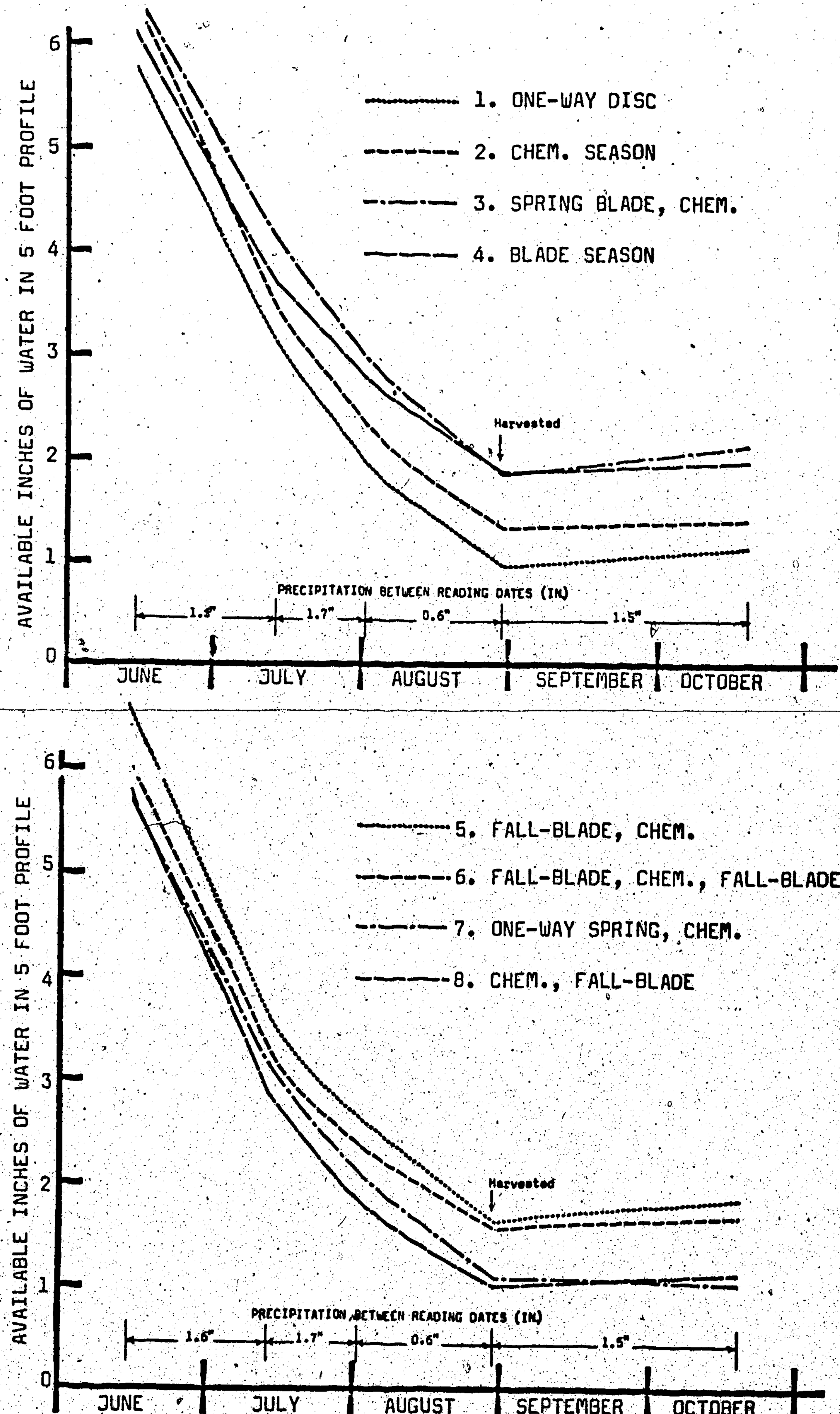


Figure 17: Soil moisture status during 1972 crop season (field A).

plots (treatments 1, 2, 3, 5, and 7). Differences were not significant when considering the overall moisture change between initial and final reading dates. Also worthy of noting was the fact that the 1.5 inches of precipitation which occurred between harvest and the October 20 moisture reading was not reflected in the total moisture status, possibly due to weed growth since harvest.

C. 1973 Summerfallow Season

The moisture status during the subsequent summerfallow season (field A) is represented in Figure 18. Initially, the one-way disc fallow (treatment 1) had significantly less available moisture than all other fallows and this relationship generally existed throughout the summerfallow season. Since weed control was effective with the one-way disc, the poor moisture status was thought to be due to high evaporation losses, possibly a result of poor infiltration characteristics. Moisture levels of all other fallows were not significantly different at any time during the summerfallow season. However, the additional moisture conserved over the first winter by treatment 6 was maintained throughout the fallow period. The fact that the moisture status of any fallow did not change relative to any other fallow stressed the importance of maximizing moisture conservation during the first winter period.

D. 1973 Crop Season

The initial moisture status of the 1973 crop year (Figure 19) indicated very little moisture gain during the second winter period

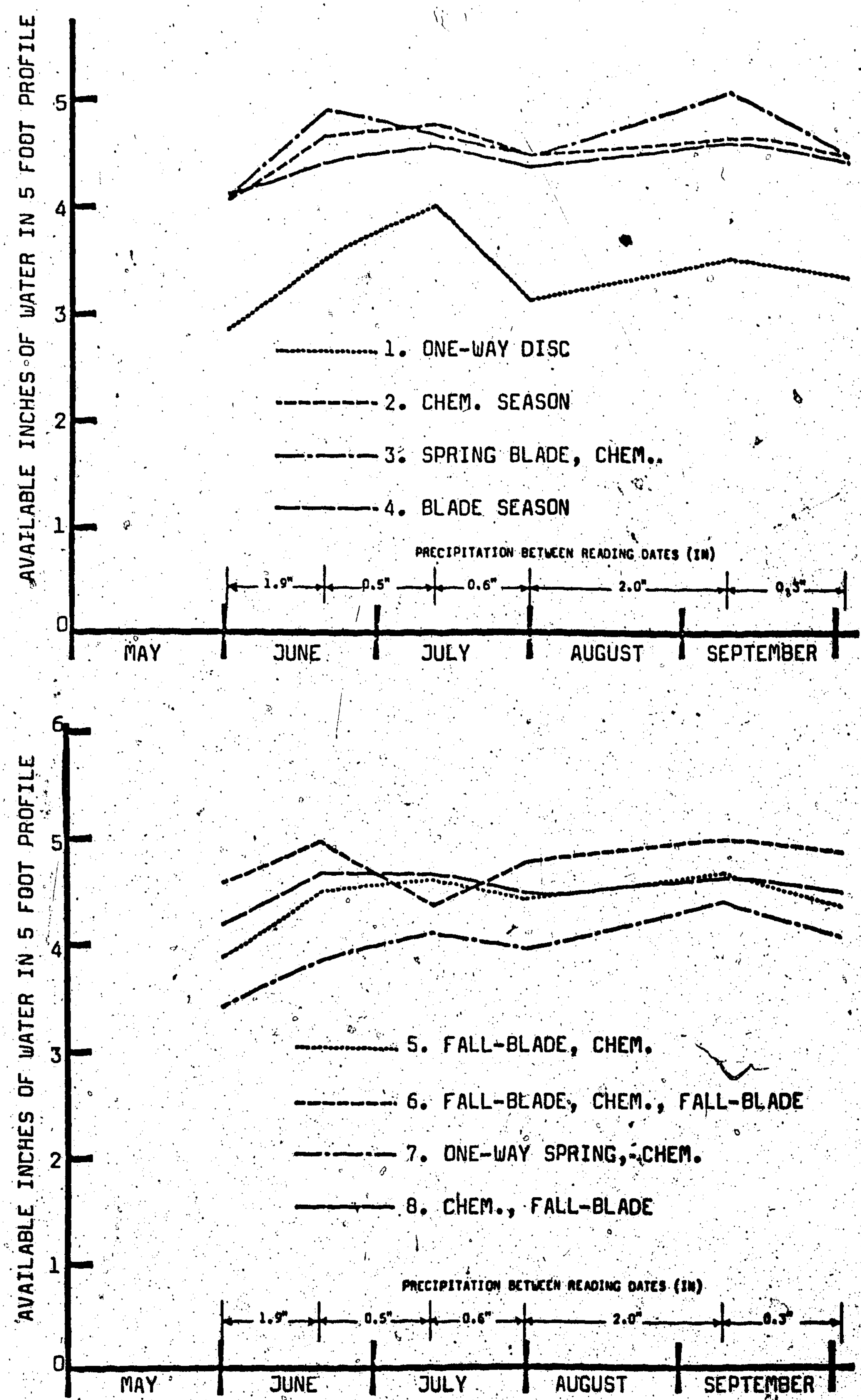
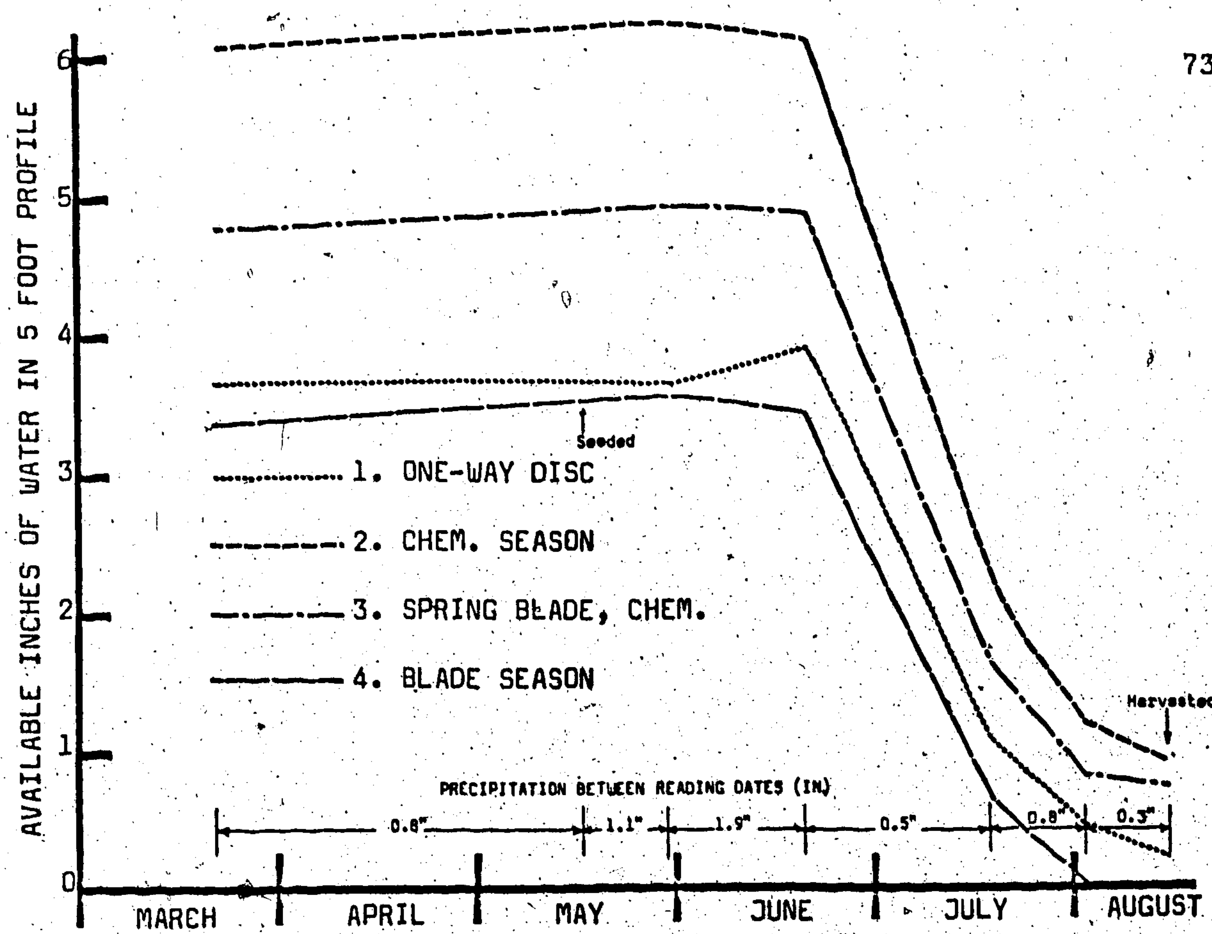


Figure 18: Soil moisture status during 1973 summerfallow season (field A).



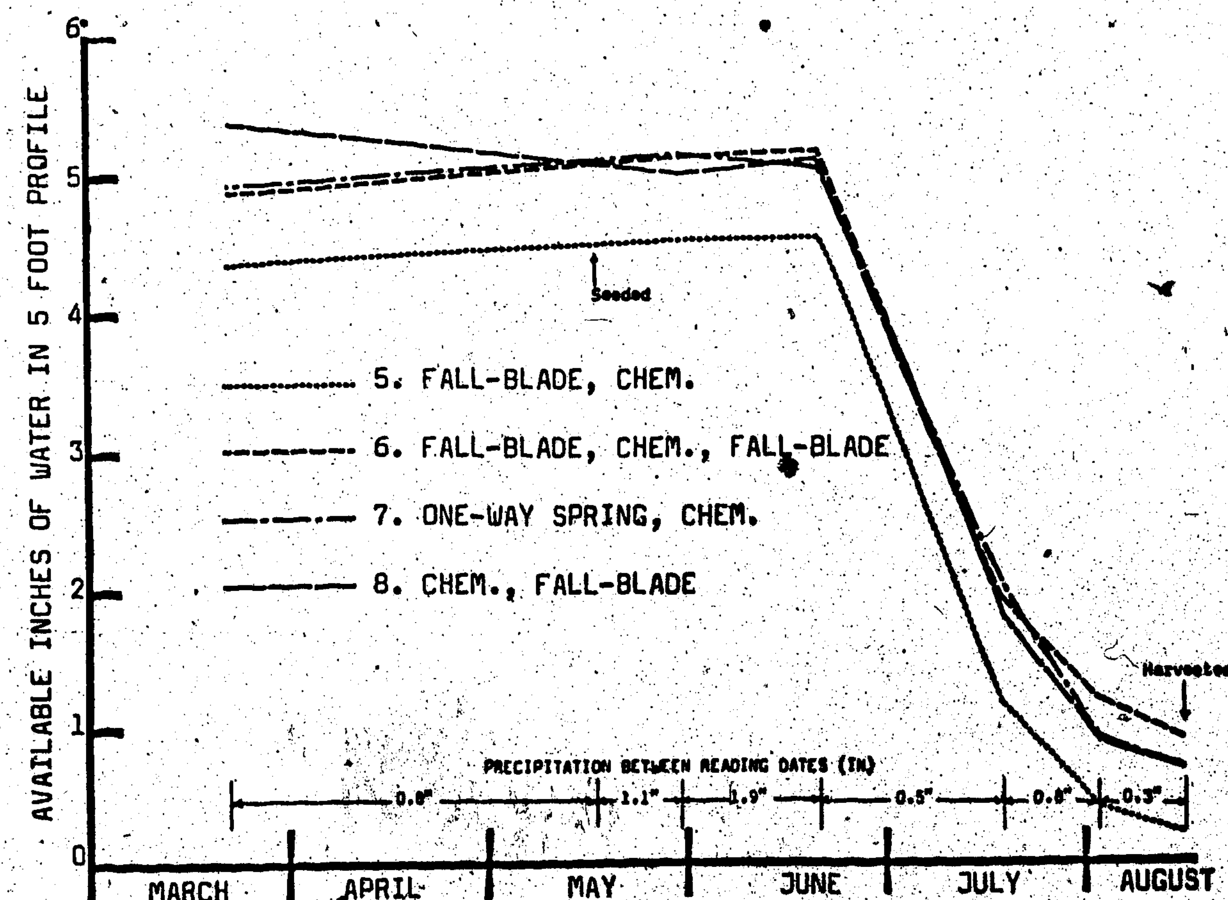
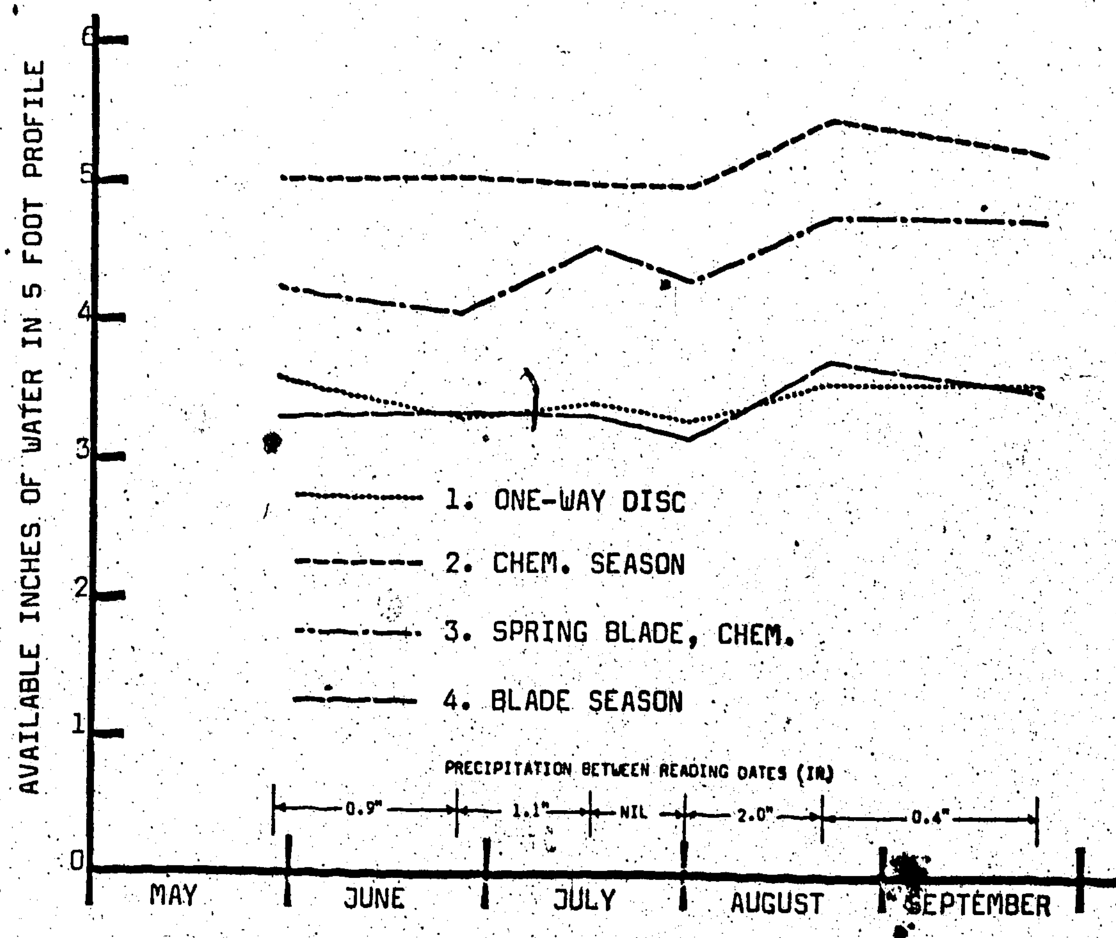


Figure 19: Soil moisture status during 1973 crop season (field 8).

when compared to the moisture status at the end of the 1972 summer-fallow season (Figure 16). Readings taken early in the spring (Figure 19) showed the chemical fallow (treatment 2) to have significantly more available moisture than the fallows which received only mechanical tillage (treatment 1 and 4). Soil moisture readings taken two weeks after seeding (May 30), again June 21 and July 19, indicated that the chemical fallow had the most available moisture of any fallow treatment (significantly more than fallow treatments 1, 3, 4, and 5) on all three dates. Soil moisture differences were not significant on either of the two August reading dates as essentially all of the available moisture had been utilized on all plots. Assuming the available moisture levels to be accurate, it would seem logical that additional moisture stress on the drier plots (treatment 1 and 4) may have had a marked effect on crop yield. The obvious moisture use differentials, as exhibited during this crop year, will be discussed in relation to crop yields in a subsequent section.

E. <u>1974 Summerfallow Season</u>

The initial neutron moisture readings of the 1974 summer-fallow season were taken on May 28, about two weeks after the first tillage and spray applications for weed control. The soil moisture status with each fallow treatment is represented in Figure 20. Despite available moisture levels ranging from a low of 3.3 inches (treatment 4) to a high of 5.5 inches (treatment 6), the initial moisture differences were not statistically significant. However, on the next reading date (June 26), some interesting and significant



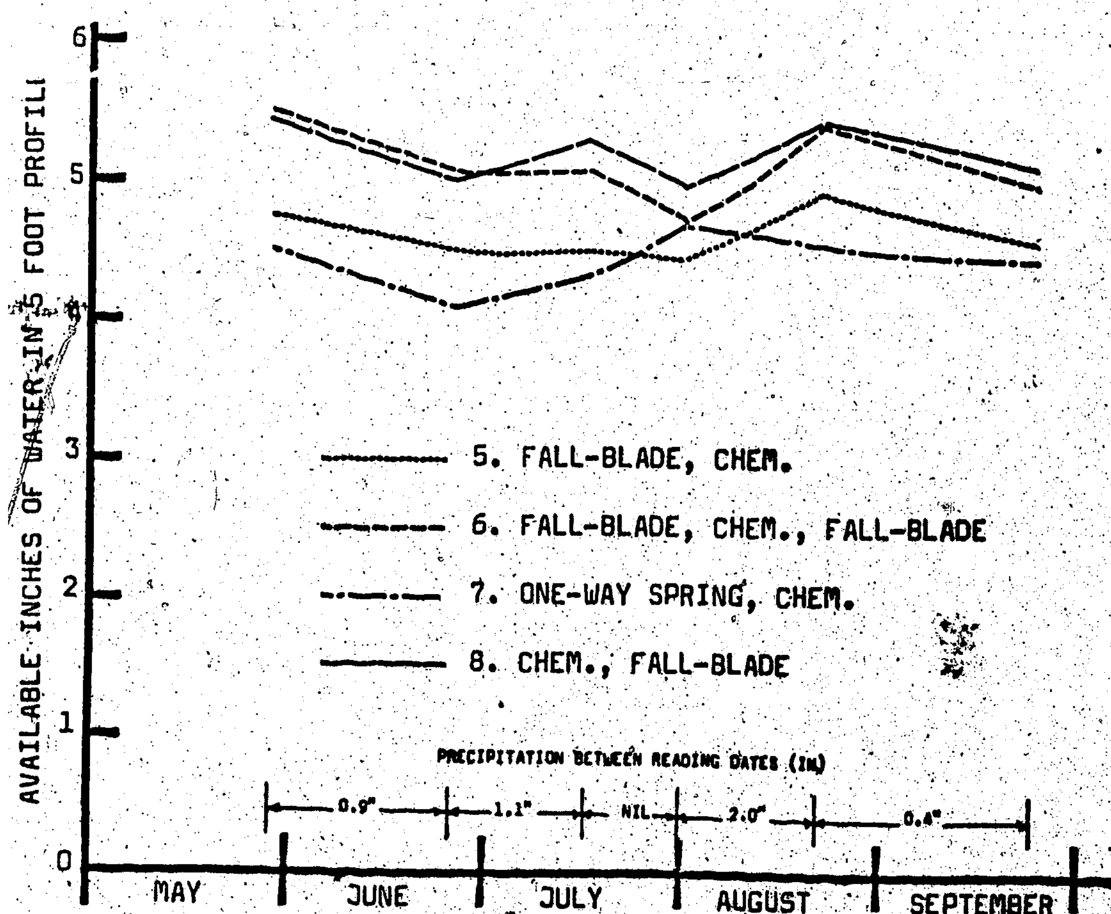


Figure 20: Soil moisture status during 1974 summerfallow season (field B).

moisture differences were evident. Although moisture differences were not significant between fallows which had received any tillage up to this point in summerfallow season (treatments 1, 3, 4, and 7), all of these fallows had significantly less available moisture than fallows which had not received any seasonal tillage (treatments 2, 5, 6, and 8). Any moisture differences existing between fallows on the next two reading dates (July 16 and 31) were not significant. In spite of precipitation being nil between the July 16 and July 31 readings, only the chemical fallow (treatment 2) was able to maintain its moisture status while the other fallows experienced slight moisture losses. Most plots showed substantial moisture gains during August; however, moisture readings on August 22 revealed that the fallows involving only mechanical tillage (treatments 1 and 4) had significantly less available moisture than all other fallows. This same relationship existed after a very dry September, during which all fallows lost moisture. Overall, soil moisture status was not significantly improved during the summerfallow season by any fallow treatment.

F. <u>1974 Crop Season</u>

As a result of substantial precipitation (3 inches) during the last week of April, the initial soil moisture status of the 1974 crop year (Figure 21) was relatively good and much improved from the final moisture reading of the 1973 summerfallow season (Figure 18). Despite the one-way disc fallow (treatment 1) having at least 0.8 inches less moisture than the other fallows, soil moisture differences were not significant at the time of seeding.

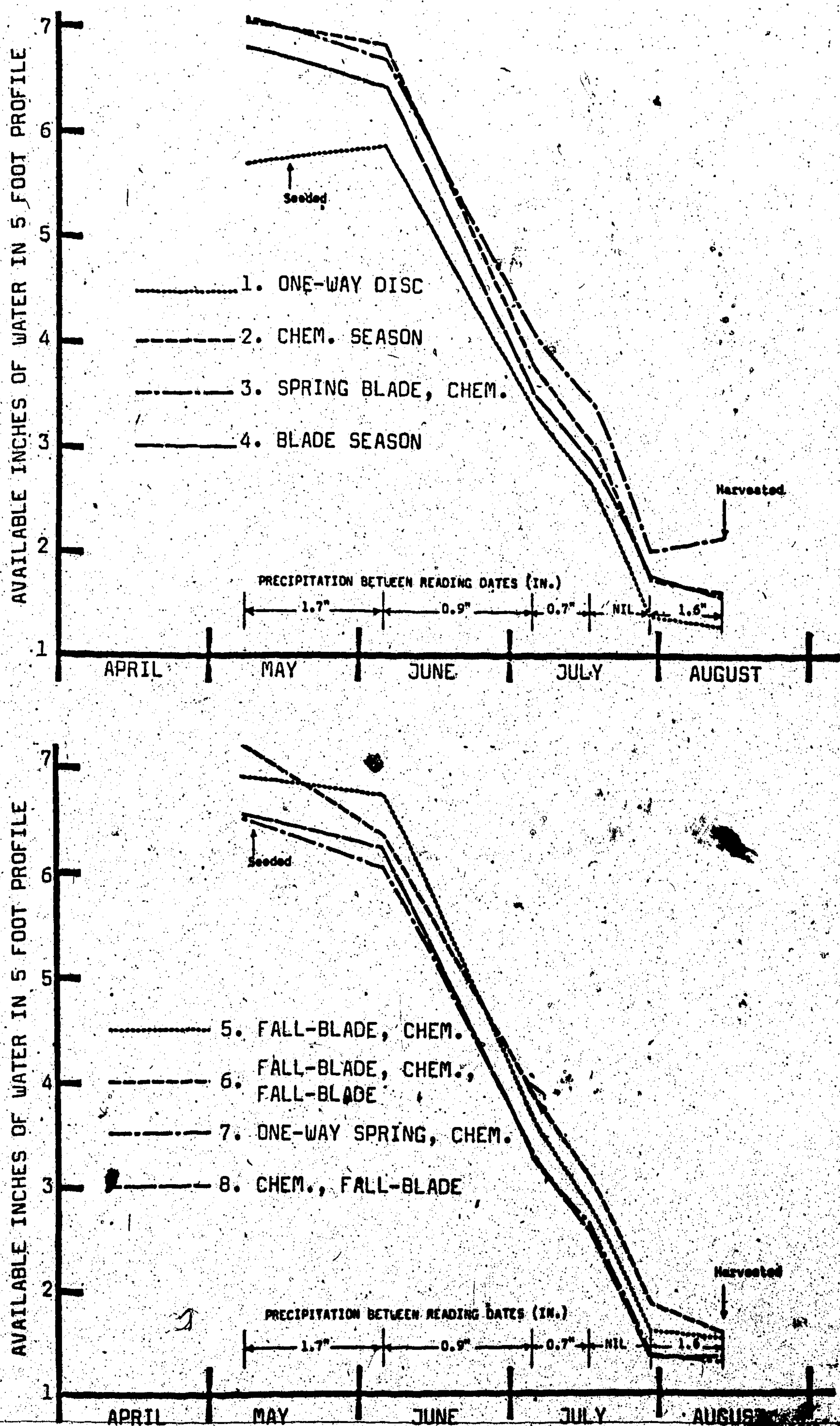


Figure 21: Soil moisture status during 1974 crop season [illegible]

In fact, moisture differences were not significant on any reading date throughout the growing season. Nor were there any significant differences regarding moisture changes between reading dates, as overall moisture depletion ranged from 4.5 inches (treatment 1) to 5.7 inches (treatment 6). Again, reserve moisture was well utilized as was evident by the low moisture levels at harvest.

Although gravimetric and neutron moisture measurements compared favorably in relative terms, it was generally observed that total soil moisture levels when determined by the neutron method were somewhat higher (0.5 to 1.0 inches higher) than those determined by the gravimetric method. This apparent discrepancy was thought to be due to the different manner in which volumetric moisture or inches of water was determined for the two methods. As previously discussed, volumetric moisture was determined by multiplying the gravimetric weight percentage by the dry bulk density of the soil at the time of sampling. The neutron method however, involved a calibration equation which employed a constant average bulk density for the total profile of the soil in question. Although extensive gravimetric data indicated that fallow treatment had little effect on total soil bulk density, there were bulk density differences among replicates. The fact that the average bulk density of the soil in this study was less than the calibrated bulk density for neutron measurement may have contributed to the apparent moisture differences.

Another factor which may have partially accounted for the moisture variation was the possible overlapping of the spheres of moisture influence. With the neutron scattering method a dry soil has a larger sphere os influence than a moist soil. This may have resulted in apparent moisture levels being slightly higher than actual, particularly when the soil was relatively dry.

Although analyses of moisture differences between treatments were also carried out according to depth, the bulk density factor (discussed above) made accurate assessment difficult, particularly since moisture differences were usually concentrated in the surface foot of soil where bulk density was highly variable.

6.5 Nitrate Nitrogen

Soil samples for NO_3-N determination were taken prior to preseeding tillage in each of the last three years of the study. Over the three years there was considerable variation in the NO_3-N content of the top 24 inches of soil both within and between treatments. A complete summary of the yearly data with analysis is given in Appendix 8. A summary of the data for the three years combined is shown in Table 8. Despite obtaining significant differences between total nitrate levels in each of the three years, when the data for the three years were analyzed together the treatment differences were not significant which is accountable to the fact that there were only two degrees of freedom for the 3 years of observations.

The general trend indicated that the chemical fallow plots (treatment 2) had lower NO_3-N values than most other plots, particularly in the surface 12 inches. For some reason, possibly poorer weed control during the summerfallow season, the blade fallow plots (treatment 4) had significantly lower nitrate levels than all other plots in 1973. The fallow plots involving the one-way disc (treatments 1 and 7) generally had the highest NO_3-N values.

TABLE 8: MEAN NITRATE-NITROGEN LEVELS IN THE SOIL PRIOR TO PRESEEDING TILLAGE (THREE-YEAR MEAN IN LB/AC)

Treatment	Depth (in.)			
	0-6	6-12	12-24	0-24
1. One-Way disc	24[bc]	19	35	78
2. Chemical fallow	13[a]	15	31	59
3. Spring-blade, chemical season	17[ab]	17	32	66
4. Blade Season	18[ab]	17	31	66
5. Fall-blade, chemical season	15[a]	16	34	65
6. Fall-blade, chemical season, fall-blade	18[ab]	17	35	70
7. One-way spring, chemical season	26[c]	18	30	74
8. Chemical season, fall-blade	18[ab]	20 D.N.S.	37 D.N.S.	75 D.N.S.

a,b,c Means with a common letter in superscript are not significantly different at the 5 percent probability level.

D.N.S. Differences not significant at the 5 percent probability level.

as might be expected. Although the differences were not usually significant, a late fall-blading prior to the second winter period (treatments 6 and 8) generally had higher nitrate levels than fallows receiving blade tillage at other times. Nitrate nitrogen levels were usually as high on plots receiving only one tillage operation as they were on the more intensively tilled plots.

In absolute terms, the nitrate levels for all treatments were quite good considering the fact that the fields involved had never received commercial fertilizer. The fact that all plots received preseeding tillage must be considered in assessing the effects that these small nitrate differences may have had on crop growth or yield.

6.6 Yields of Spring Wheat

Wheat yields were highly variable over the 7-year study period as yearly means ranged from a low of 20.1 bus/ac (1973) to a high of 37.4 bus/ac (1969). In every year, except 1969 when yields from all plots were high due to substantial seasonal precipitation (nearly 8 inches), there were significant yield differences between fallow treatments. The mean yields and mature plant heights for the 7-year period are given in Table 9. Summaries of yearly means and analyses for both plant heights and yields are given in Appendices 9 and 10 respectively.

Also included in Table 9 are the mean available moisture levels (previously discussed in subsection 6.4.1) and the mean quantities of soil moisture depletion during the growing season,

TABLE 9: AVAILABLE SPRING MOISTURE, RESERVE MOISTURE DEPLETION, MATURE PLANT HEIGHT, AND YIELD RESULTS (1968-74)

	Available Spring Moisture to a 5 Foot Depth (in.) (1969-74)	Reserve Moisture Depletion over Growing Season (in.) (1969-74)	Mature Plant Height (in.)	Spring Wheat Yield (bus/ac)
1. One-way disc	5.0^{a}	5.2^{a}	28.2^{a}	25.6^{a}
2. Chemical fallow	6.2^{d}	6.0^{c}	29.5^{bc}	27.7^{b}
3. Spring-blade, chemical season	5.9^{cd}	5.8^{c}	28.9^{ab}	25.5^{a}
4. Blade season	5.0^{a}	5.1^{a}	28.8^{ab}	25.1^{a}
5. Fall-blade, chemical season	5.5^{abc}	5.6^{bc}	28.9^{ab}	26.7^{ab}
6. Fall-blade, chemical season, fall-blade	5.7^{bc}	5.7^{bc}	28.9^{ab}	27.2^{ab}
7. One-way spring, chemical season	5.4^{abc}	5.7^{bc}	28.8^{ab}	26.3^{ab}
8. Chemical season, fall-blade	5.3^{ab}	5.6^{bc}	29.8^{c}	30.0^{c}

a,b,c,d Column means with a common letter in the superscript are not significantly different at the 5 percent probability level.

the latter quantities being the difference of the before-seeding and after-harvest soil moisture levels as determined by gravimetric sampling. A complete summary of these values with analysis is given in Appendix 11.

The analysis of all years combined (Table 9) showed that the chemical fallow with a fall-blading (treatment 8) produced significantly taller crops and higher yields than the other treatments, which was the case in five of the seven years studied. Yield differences were not significant between other fallow treatments involving some degree of mechanical tillage. The chemical fallow (treatment 2) ranked second to treatment 8 and produced significantly higher yields than treatments 1, 3, and 4.

The significant yield differences were not totally explained by differences in available spring moisture. Despite only having average soil moisture status, the chemical fallow with a fall-blading (treatment 8) consistently produced taller crops and higher yields than did fallows which had more soil moisture. Although the chemical fallow (treatment 2) had nearly 1 inch more soil moisture than the chemical fallow with a fall-blading (treatment 8), the corresponding yields for chemical fallow averaged 2.3 bus/ac less. The poorer moisture status observed with the fallows involving only mechanical tillage (treatments 1 and 4) generally resulted in shorter crops and lower spring wheat yields.

The figures representing the apparent reserve moisture use corresponded favorably with those indicating the available moisture status. Apparent moisture use on the fallows involving only mechanical tillage (treatments 1 and 4) was significantly less than that on all other fallows. Differences in moisture use were not significant between any of the other fallow treatments.

A factor which may have contributed to some of the yield variation was that of nitrate-nitrogen status, discussed in the previous section. Although the three-year means of total NO_3-N were not significantly different, there were indications of nitrate depression with the chemical fallow (treatment 2). This depression in nitrate status may have been sufficient in preventing the growing wheat crop from making maximum and most efficient use of the additional reserve moisture apparent with chemical fallow. Also noted was the fact that higher than average NO_3-N levels were apparent on the fallow (treatment 8) which produced the highest yields.

Though not conclusive, two years data (1973 and 1974) indicated differences between treatments with regard to plant counts taken soon after emergence. The two-year averages indicated 28 plants/linear yd and 31 plants/linear yd for the one-way and blade fallows respectively, compared to 36 plants/yd on the chemical fallow with fall-blading (the highest yielding fallow). Plant counts on the other fallows ranged from 32 plants/yd to 34 plants/yd. Corresponding moisture differentials in the surface foot of soil at the time of seeding were thought to be the major contributor to these emergence differences. Plots receiving little or no tillage during the summerfallow season generally had better surface moisture than those plots which received extensive fallow tillage.

Throughout the study period differential weed growth during the crop year was not considered to be a major factor in affecting wheat yields. Moderate infestations of wild oats in some years required the application of specialized herbicides; however, these infestations were not considered to be more localized on plots of particular fallow treatments. In at least two years, early infestations of green foxtail particular to the chemical fallow plots may have resulted in some yield reduction.

6.7 Regression Analysis

Despite having only 7 years data, a multiple stepwise regression analysis was applied to the independent variables of available soil moisture, surface residue, and effective precipitation during the growing season. The dependent variable was spring wheat yield for which the general equation is given below:

$$Y = a + b_1(AMR) + b_2(SR) + b_3(P)$$

where Y - spring wheat yield (bus/ac)

a - constant (bus/ac)

b_1, b_2, b_c - regression coefficients for corresponding independent variables

AMR - available spring moisture reserve to a 4 foot depth (in.)

SR - surface residue prior to seedbed preparation (lb/ac)

P - effective precipitation between the dates of spring moisture sampling and swathing (in.)

The observations of available moi[illegible]eserves (AMR) to a depth of four instead of 5 feet were sele[illegible] because of one additional year's data (1968). Since surface residue data (SR) was only available for 6 years (1969-74), the 6-year means for each treatment were determined and used as the respective observations of residue levels for 1968. Effective precipitation (P) between the dates of spring moisture sampling and swathing was considered to be the sum of all daily precipitation quantities amounting to more than 0.10 inches.

Regression equations, coefficients of determination (R^2), and relevant simple correlations (r) for each fallow treatment are given below:

1. One-way disc

$$Y = -24.6 + 9.27^{*}(AMR) + .016(SR) + 1.10(P)$$

$R^2 = .80$ $\qquad$ r(AMR,Y) = .83
r(P,Y) = .51

2. Chemical fallow

$$Y = -13.9 + 5.41(AMR) + .0012(SR) + 1.59(P)$$

$R^2 = .66$ $\qquad$ r(ARM,Y) = .74
r(P,Y) = .44

3. Spring-blade, chemical season

$$Y = -34.1 + 8.71^{**}(AMR) + .0039^{**}(SR) + 1.54^{*}(P)$$

$R^2 = .97$ $\qquad$ r(AMR,Y) = .86
r(P,Y) = .41

4. Blade only

$$Y = -23.3 + 6.03(AMR) + .010(SR) + .99(P)$$

$R^2 = .61$ $\qquad$ r(AMR,Y) = .50
r(P,Y) = .48

5. Fall-blade, chemical season

$$Y = -26.6 + 8.1^{*}(AMR) + .0065^{*}(SR) - .02(P)$$

$R^2 = .89$ $\qquad$ r(AMR,Y) = .66
r(P,Y) = .35

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*, ** Coefficients significant at the 5 and 1 percent probability levels respectively.

6. Fall-blade, chemical season, fall-blade

$$Y = -46.3 + 13.1^{*}(AMR) + .0089(SR) - .91(P)$$

$$R^2 = .87 \qquad r(AMR,Y) = .63 \qquad r(P,Y) = .35$$

7. One-way spring, chemical season

$$Y = -35.9 + 7.8^{*}(AMR) + .0158^{*}(SR) + 2.03(P)$$

$$R^2 = .87 \qquad r(AMR,Y) = .60 \qquad r(P,Y) = .43$$

8. Chemical season, fall-blade

$$Y = -13.7 + 6.48^{**}(AMR) + .0031(SR) + 1.2(P)$$

$$R^2 = .92^{*} \qquad r(AMR,Y) = .90^{*} \qquad r(P,Y) = .28$$

9. All fallow treatments combined

$$Y = -38.5 + 8.85^{**}(AMR) + .0092^{*}(SR) + 1.38(P)$$

$$R^2 = .90^{*} \qquad r(AMR,Y) = .75 \qquad r(P,Y) = .40$$

Although the above equations may not be valid for yield prediction, they did illustrate some interesting relationships. As there were only seven observations for each of the three independent variables, the correlation coefficients required to be statistically significant at the 5 percent level were relatively high (r or R = .95 and R^2 = .90). Despite this fact, some of the regression equations proved to be significant (Equations 3, 8, and 9).

Two equations, representing the chemical fallow and blade-only treatments (Equation 2 and 4), were obviously unable to accurately describe yield variation on the basis of the given parameters. This suggests that other factors may have had some significant influence on yield variation. In the chemical fallow treatment, yields may have been depressed by some other factor, possibly the poorer nitrate status (previously discussed) relative to the high moisture status. Similarly, the low coefficient of determination (.61) for the blade-only equation suggests that the given parameters were too variable or other contributing factors were necessary to accurately describe yield variation.

Generally, it appeared that available moisture reserves accounted for most of the yield variation as indicated by the significant regression coefficients in most of the equations. The correlation coefficients (r) also indicated that reserve moisture was more highly correlated to yields than was seasonal precipitation. If seasonal precipitation had been expressed in terms of weekly or monthly intervals, then more accurate estimates of yield variation may have been obtained.

The regression analysis also indicated that little or no correlation existed between spring levels of surface residue and reserve moisture. Surface residue quantities were highly variable between years and generally more dependent on the previous year's yield rather than tillage treatment. Interesting to note, however, is the fact that the regression coefficients were usually more significant for surface residue levels than for seasonal precipitation quantities.

The regression equation representing yield with all fallow treatments combined (Equation 9) also indicated that moisture reserves were highly significant and accounted for most of the yield variation. The relatively high correlation coefficient between yield and moisture reserve (.75) also suggests the importance of maximizing moisture during the fallow period.

Regression equations are only accurate for prediction within the range covered by the original observations. Despite being few in number there was a wide range of observations for each of the variables included in the regression analyses; suggesting that the above equations may be of some practical significance. Since seasonal rainfall was undoubtedly more important than the analyses indicated, the timeliness of precipitation was probably more important than quantity alone and should be considered in analyses of this type.

CHAPTER 7

SUMMARY AND CONCLUSIONS

The weather during the study period tended to lend itself to a study of minimum tillage practices. Seasonal precipitation was generally below average throughout the study and this undoubtedly contributed to some of the observed treatment differences regarding moisture conservation. Had precipitation levels been normal or above normal during the period, differences may not have been as significant. However, data obtained from this study did illustrate the importance of maximizing soil moisture conservation, particularly during the dry growing seasons when the crop relied heavily on moisture reserves.

Keeping the number of fallow tillage operations to a minimum through chemical weed control reduced the hazards of erosion by conserving more crop residue then conventional or more intensive tillage practices. Minimizing fallow tillage generally resulted in greater soil moisture conservation and ultimately higher spring wheat yields. However, without adequate weed control the beneficial effects resulting from mechanical tillage or chemical fallow were secondary. If weeds were effectively controlled with herbicides, fallow tillage was not necessary to maximize moisture conservation and maintain high crop yields.

Under soil and climatological conditions of the study, the following conclusions were drawn:

1. Intensive summerfallow tillage was not necessary for and may have limited soil moisture conservation.
2. Fallows receiving only chemical weed control maintained higher levels of crop residue and conserved more soil moisture than conventional tillage practices.
3. Fall-blading (after harvest) did not result in greater over-winter moisture conservation, but effectively controlled winter annual weeds which normally were a problem during the summerfallow season.
4. Weed control was generally more important during the summerfallow season with regard to moisture conservation than were the soil physical characteristics resulting from fallow method.
5. Fall-blading (after the summerfallow season) did not generally provide better moisture intake from snowmelt but improved the soil nitrate status.
6. Upright crop residue was more effective for trapping snow and conserving moisture from snowmelt than equivalent quantities of loose crop residue.
7. The moisture conservation characteristics created by intensive tillage practices were carried over from season to season.
8. This study suggests that blading or sweep tillage should not be used exclusively as a means of weed control during a fallow season.
9. Sweep tillage was not an effective method of weed control when the soil to tilling depth was relatively moist, as was normally the case early in the summerfallow season.

10. Fallowing with a one-way disc was a very effective means of weed control and maintained high nitrate levels but afforded little protection from wind erosion and generally exhibited poor moisture conservation characteristics which were in turn reflected in poorer yields.

11. Moisture conservation during the summerfallow period was inversely related to the soil moisture status at the beginning of the period.

12. The additional moisture conserved by a particular fallow treatment was generally reflected in crop growth and yield.

13. In years of abundant precipitation during the growing season, the previous year's fallow methods did not have a significant effect on crop yield.

14. More than one tillage operation during the fallow period did not significantly improve the soil nitrate status.

15. Although not critical, trends indicated reduced nitrate nitrogen status with chemical fallow.

16. Moisture conservation was most efficient during the first fall and winter of the fallow cycle and was maximized by controlling fall weed growth and maintaining maximum levels of upright crop residue to trap snow and prevent erosion.

17. If, after the first winter period, the available soil moisture status to a 5 foot depth was greater than 70 percent of field capacity, summerfallow did not improve the moisture status, irrespective of fallow method. In such cases, summerfallow

would be difficult to justify on the basis of moisture conservation alone.

18. Eighty percent of the theoretical available field capacity (to a 5 foot depth) seemed to be the optimum soil moisture status possible with any fallow method.

19. Complete chemical fallow may be possible with the wide range of herbicides presently available, but a detailed cost analysis is necessary to determine if chemical weed control can compete with cultivation.

20. If weed populations are such that effective control can be achieved by the application of such economical herbicides as 2,4-D then tillage may be avoided.

21. The highly variable factors of weather, soil characteristics, and weed populations make it difficult, if not impossible, to define one tillage system, minimum or otherwise, which will always optimize the conditions necessary for maximum production.

22. The ultimate summerfallow system is one which will economically control weeds, prevent erosion, and be sufficiently adaptable to the everchanging conditions of dryland agriculture.

CHAPTER 8

RECOMMENDATIONS FOR FURTHER RESEARCH

1. Further studies of this nature utilizing a wide range of crops under a variety of soil and climatological conditions would enable a more accurate assessment of minimum tillage practices and their general applicability.
2. More suitable herbicides must be developed that will economically control weeds during the fallow cycle. The ideal herbicide would be a pre-emergent type that could be applied after harvest and effectively control weeds throughout the 20-month fallow period without exhibiting toxic effects on the subsequent crop.
3. Prairie farmers are presently spending between $6.00/ac and $8.00/ac on tillage in a typical fallow-crop cycle. Despite possible benefits with chemical fallow, the cost of chemical weed control must compare favorably with tillage to be of practical significance to the farmer.
4. Further studies are suggested that would establish the conditions under which zero tillage may be feasible.
5. A greater understanding is required regarding the soil physical effects created by minimum or zero tillage practices. If the elimination of tillage improves the infiltration characteristics as was suggested in the literature review (Subsection 2.3.1), then further research is necessary to determine the processes involved in creating these effects. The compaction effects of tillage and chemical fallow also warrants continued study.

6. Long-term research is necessary to determine if minimum and zero tillage will adversely affect soil nutrient levels. The conditions created by an untilled soil may affect the efficiency of nutrient uptake. This also involves the problem of finding suitable methods of fertilizer application.
7. More specialized seeding machinery is also required that will provide more effective seed placement under those conditions normally associated with chemical fallow.
8. Further research is necessary to determine the microbiological effects that may arise from the elimination of tillage. Crops may be more or less susceptible to disease in untilled soil conditions.
9. Conventional tillage systems will likely continue to be the most widely accepted systems and therefore require continued research to improve upon their efficiency.

CHAPTER 9

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APPENDICES

APPENDIX 1: AVERAGE TEXTURAL ANALYSIS OF SOIL FROM SEVERAL PLOTS OF FIELDS 'A' AND 'B'

Depth (in.)	Sand (%)	Silt (%)	Clay (%)	Classification
0-12	33	30	37	Clay loam
12-24	32	28	40	Clay loam - Clay
24-36	36	24	40	Clay loam - Clay
36-54	38	25	36	Clay loam

APPENDIX 2: MEAN QUANTITIES AND ANALYSIS OF TOTAL SURFACE RESIDUE ON PLOTS PRIOR TO SEEDBED PREPARATION (1969-74)

	Loose Residue (lb/ac)							
	Treatment							
Year	1	2	3	4	5	6	7	8
1969	61	2237	1250	1425	2388	1580	715	1465
1970	257	2311	1509	1655	1631	1464	684	1707
1971	487	3119	3256	2617	3294	3131	1515	3230
1972	34	2131	1420	870	1757	1322	599	1960
1973	89	3435	2194	1915	2472	1844	838	2367
1974	139	1350	634	977	1527	1214	613	1016
Ave.	178	2430	1710	1576	2178	1759	828	1958
	Anchored Residue (lb/ac)							
1969	7	388	86	310	196	134	76	189
1970	26	282	134	22	192	163	75	142
1971	11	310	316	34	208	95	65	82
1972	0	761	94	43	95	32	43	35
1973	0	276	139	0	174	48	14	55
1974	0	464	247	11	201	70	19	195
Ave.	7	414	169	70	178	90	49	116
Total Ave.	185 a	2844 f	1879 cd	1646 c	2356 e	1849 cd	877 b	2074 de

Source	Degrees of Freedom	Sum of Squares (x 10^6)	Mean Squared (x 10^6)	F-Value
TREAT	7	27.98	4.00	35.4**
YEAR	5	14.17	2.83	25.1
ERROR	35	4.00	0.113	
TOTAL	47	46.09		

a,b,c,d,e,f Means with a common letter below are not significantly different at the 5 percent probability level.

** Significant at the 1 percent probability level.

APPENDIX 3: SOIL MOISTURE TENSION DATA (INCHES OF WATER) AT THEORETICAL WILTING POINT (15 ATM) AND FIELD CAPACITY (1/3 ATM)

FIELD A		0-12"		12-24"		24-36"		36-48"		48-60"		Total	
Treat	Rep	1/3 atm	15 atm	1/3 atm	15 atm	1/3 atm	15 atm	1/3 atm	15 atm	1/3 atm	15 atm	1/3 atm	15 atm
1	1	2.83	1.42	3.33	1.49	3.40	1.37	2.84	1.29	2.35	1.16	14.75	6.73
	2	3.02	1.48	3.42	1.52	3.40	1.52	2.60	1.22	2.58	1.26	15.02	7.00
	3	3.01	1.45	4.08	1.83	4.14	1.65	3.55	1.45	3.06	1.31	17.84	7.74
	4	2.79	1.52	3.44	1.69	3.54	1.58	2.78	1.29	2.61	1.28	15.16	7.36
	5	2.93	1.34	3.74	1.77	3.92	1.50	3.33	1.26	3.00	1.30	16.92	7.17
	6	2.77	1.22	3.37	1.39	3.06	1.20	2.93	1.14	2.50	1.09	14.68	6.04
	Ave.	2.89	1.40	3.56	1.61	3.58	1.47	3.00	1.28	2.68	1.23	15.73	7.01
2	1	3.38	1.60	4.22	1.77	4.05	1.58	3.14	1.27	2.81	1.20	17.60	7.42
	2	3.13	1.36	3.38	1.23	3.44	1.41	2.76	1.15	2.88	1.21	15.59	6.36
	3	2.91	1.35	4.59	1.87	3.53	1.44	3.00	1.29	2.46	1.12	16.48	7.05
	4	2.96	1.43	4.09	1.78	3.27	1.37	2.65	1.22	2.73	1.36	15.70	7.16
	5	1.92	1.51	3.29	1.44	3.07	1.37	2.62	1.31	2.70	1.32	14.60	6.93
	6	3.05	1.38	3.19	1.40	2.60	1.08	2.30	1.03	2.78	1.28	13.92	6.21
	Ave.	2.89	1.44	3.79	1.58	3.33	1.38	2.74	1.21	2.73	1.25	15.65	6.86
3	1	3.09	1.44	3.81	1.68	3.77	1.51	2.81	1.24	2.93	1.24	16.41	7.11
	2	3.34	1.60	3.65	1.62	3.55	1.56	1.94	1.33	2.40	1.10	16.88	7.21
	3	3.05	1.45	4.06	1.73	4.08	1.75	3.59	1.60	3.04	1.34	15.82	7.87
	4	2.92	1.34	3.72	1.60	3.73	1.45	2.81	1.16	2.91	1.22	16.09	6.77
	5	2.92	1.38	3.65	1.57	3.70	1.33	3.12	1.36	2.86	1.22	16.25	6.86
	6	2.88	1.37	3.25	1.38	2.95	1.31	2.95	1.31	2.70	1.24	14.73	6.50
	Ave.	3.03	1.43	3.69	1.60	3.63	1.47	2.87	1.33	2.81	1.23	16.03	7.05
4	1	3.00	1.39	3.90	1.62	3.46	1.40	2.78	1.22	2.64	1.23	15.78	6.86
	2	3.15	1.45	3.53	1.44	2.79	1.04	2.55	1.28	2.47	1.09	14.49	6.10
	3	2.88	1.40	3.04	1.43	3.14	1.28	2.77	1.20	2.58	1.18	14.41	6.49
	4	2.82	1.50	3.26	1.64	3.22	1.40	2.77	1.19	2.55	1.31	14.55	7.24
	5	2.87	1.39	3.38	1.49	3.17	1.39	2.68	1.25	2.51	1.16	14.61	6.78
	6	2.82	1.22	3.96	1.68	3.01	1.32	2.81	1.21	2.47	1.11	15.05	6.51
	Ave.	2.92	1.39	3.51	1.55	3.13	1.30	2.73	1.22	2.54	1.18	14.81	6.66

APPENDIX 3: CONTINUED

FIELD A

Treat	Rep	0-12" 1/3 atm	0-12" 15 atm	12-24" 1/3 atm	12-24" 15 atm	24-36" 1/3 atm	24-36" 15 atm	36-48" 1/3 atm	36-48" 15 atm	48-60" 1/3 atm	48-60" 15 atm	Total 1/3 atm	Total 15 atm
5	1	2.82	1.54	3.86	1.65	3.09	1.40	2.65	1.23	2.33	1.20	14.75	7.05
	2	3.18	1.59	3.56	1.59	3.21	1.51	2.62	1.25	2.94	1.36	15.51	7.30
	3	3.07	1.51	4.09	1.69	3.79	1.61	3.04	1.35	2.80	1.26	16.79	7.42
	4	2.98	1.35	3.46	1.57	3.11	1.32	2.62	1.18	2.57	1.29	14.74	6.71
	5	3.04	1.41	3.37	1.44	3.92	1.54	3.28	1.32	3.09	1.25	16.70	6.96
	6	2.98	1.36	3.06	1.28	2.95	1.20	2.55	1.09	2.50	1.10	14.06	6.03
	Ave.	3.01	1.46	3.57	1.54	3.34	1.43	2.79	1.24	2.70	1.24	15.42	6.91
6	1	2.94	1.46	3.80	1.45	3.04	1.28	2.54	1.13	2.72	1.28	15.04	6.60
	2	3.06	1.63	3.59	1.50	2.88	1.19	2.82	1.23	2.51	1.16	14.86	6.51
	3	3.00	1.35	3.84	1.55	3.17	1.21	2.71	1.16	2.70	1.31	15.42	6.58
	4	2.94	1.34	3.82	1.64	3.16	1.35	2.81	1.33	2.95	1.41	15.68	7.07
	5	3.00	1.41	3.63	1.51	3.55	1.41	2.86	1.27	2.78	1.24	15.82	6.84
	6	2.89	1.38	3.49	1.39	2.71	1.08	2.59	1.15	2.32	1.05	13.98	6.05
	Ave.	2.97	1.43	3.70	1.51	3.08	1.25	2.72	1.21	2.66	1.24	15.13	6.61
7	1	3.36	1.70	4.26	1.95	4.56	1.92	4.27	1.65	3.33	1.43	19.78	8.65
	2	3.09	1.47	3.69	1.46	2.81	1.16	2.74	1.15	2.53	1.16	14.86	6.40
	3	3.99	1.90	4.78	2.02	4.54	1.93	4.24	1.78	3.03	1.35	20.58	8.98
	4	2.88	1.35	3.84	1.66	4.02	1.44	3.04	1.19	3.01	1.26	16.79	6.90
	5	2.96	1.40	3.69	1.60	3.54	1.48	3.05	1.30	2.71	1.25	15.95	7.03
	6	2.93	1.39	3.82	1.66	3.66	1.49	3.12	1.38	2.58	1.19	16.11	7.11
	Ave.	3.20	1.54	4.01	1.72	3.86	1.57	3.41	1.41	2.86	1.27	17.34	7.51
8	1	3.38	1.54	4.49	1.94	4.74	2.03	4.43	1.88	4.05	1.63	21.09	9.02
	2	3.28	1.50	4.09	1.60	4.40	1.77	3.51	1.43	2.99	1.26	18.27	7.62
	3	2.93	1.20	3.67	1.71	4.04	1.67	2.79	1.20	3.45	1.49	16.88	7.27
	4	3.27	1.54	4.20	1.86	3.70	1.54	3.26	1.40	2.86	1.25	17.29	7.59
	5	2.91	1.37	3.71	1.56	3.29	1.43	2.83	1.21	2.72	1.28	15.46	6.85
	6	3.01	1.47	3.32	1.47	2.92	1.29	2.73	1.20	3.07	1.41	15.05	6.84
	Ave.	3.13	1.44	3.91	1.69	3.85	1.62	3.26	1.39	3.19	1.39	17.34	7.53

APPENDIX 3: CONTINUED

FIELD B		0-12"		12-24"		24-36"		36-48"		48-60"		Total	
Treat	Rep	1/3 atm	15 atm	1/3 atm	15 atm	1/3 atm	15 atm	1/3 atm	15 atm	1/3 atm	15 atm	1/3 atm	15 atm
1	1	3.03	1.40	3.03	1.29	3.18	1.32	2.83	1.22	3.24	1.46	15.31	6.69
	2	3.48	1.70	3.41	1.71	2.82	1.25	2.80	1.36	2.49	1.16	15.00	7.18
	3	3.11	1.45	2.89	1.24	2.73	1.22	2.70	1.24	2.77	1.28	14.20	6.43
	4	2.94	1.39	3.00	1.28	2.75	1.29	2.44	1.22	2.61	1.25	13.74	6.43
	5	2.58	1.31	3.41	1.74	3.78	2.06	2.92	1.27	4.04	1.68	16.73	8.06
	6	3.11	1.54	3.49	1.54	3.63	1.47	3.22	1.37	3.10	1.36	16.55	7.28
	Ave.	3.04	1.46	3.20	1.47	3.15	1.44	2.82	1.28	3.04	1.36	15.26	7.01
2	1	3.09	1.48	3.10	1.28	2.68	1.22	2.58	1.23	2.44	1.21	13.89	6.42
	2	2.76	1.38	2.97	1.37	2.61	1.20	2.35	1.07	2.36	1.11	13.05	6.13
	3	3.28	1.55	2.94	1.24	2.64	1.20	2.56	1.05	2.42	.95	13.84	5.99
	4	3.35	1.47	3.16	1.15	2.57	1.05	2.67	1.06	2.81	1.20	14.46	5.92
	5	2.99	1.31	3.00	1.25	2.89	1.23	2.74	1.21	2.98	1.31	14.60	6.31
	6	3.02	1.36	3.59	1.52	3.65	1.44	3.18	1.34	3.05	1.33	16.49	6.99
	Ave.	3.08	1.42	3.13	1.30	2.84	1.22	2.68	1.16	2.68	1.18	14.39	6.29
3	1	3.44	1.47	3.58	1.38	2.83	1.17	2.43	1.12	2.47	1.09	14.75	6.33
	2	3.15	1.47	2.82	1.21	2.40	1.05	2.37	1.09	2.54	1.07	13.28	5.89
	3	3.24	1.65	2.92	1.31	2.96	1.26	2.63	1.12	2.73	1.22	14.48	6.56
	4	3.38	1.33	2.94	1.15	2.74	1.09	2.63	1.09	2.55	1.16	14.21	5.92
	5	3.00	1.48	3.50	1.54	3.41	1.31	2.94	1.20	2.68	1.19	15.53	6.72
	6	3.09	1.52	3.97	1.77	3.80	1.57	2.98	1.17	2.75	1.17	16.59	7.20
	Ave.	3.22	1.50	3.29	1.39	3.02	1.24	2.66	1.13	2.62	1.15	14.80	6.44
4	1	3.52	1.72	3.35	1.36	2.91	1.35	2.88	1.37	2.94	1.34	15.60	7.24
	2	3.73	1.68	3.36	1.30	3.02	1.26	2.76	1.29	2.78	1.25	15.65	6.78
	3	3.19	1.58	3.77	1.64	3.23	1.47	3.18	1.45	3.13	1.39	16.50	7.53
	4	3.07	1.51	2.64	1.25	2.67	1.31	2.53	1.29	2.57	1.27	13.48	6.63
	5	3.00	1.48	3.18	1.40	2.76	1.27	3.53	1.93	2.87	1.32	15.34	7.40
	6	3.52	1.68	3.83	1.68	3.52	1.44	2.72	1.23	2.85	1.28	16.44	7.31
	Ave.	3.34	1.61	3.36	1.44	3.02	1.35	2.93	1.43	2.86	1.31	15.50	7.15

APPENDIX 3: CONTINUED

FIELD B

Treat	Rep	0-12" 1/3 atm	0-12" 15 atm	12-24" 1/3 atm	12-24" 15 atm	24-36" 1/3 atm	24-36" 15 atm	36-48" 1/3 atm	36-48" 15 atm	48-60" 1/3 atm	48-60" 15 atm	Total 1/3 atm	Total 15 atm
5	1	3.32	1.60	3.09	1.32	2.70	1.12	2.21	1.08	2.66	1.33	13.98	6.55
	2	3.43	1.73	3.52	1.48	3.00	1.42	2.76	1.44	2.53	1.22	15.24	7.29
	3	3.44	1.56	3.55	1.41	3.23	1.26	2.78	1.19	3.10	1.34	16.10	6.76
	4	2.94	1.45	2.71	1.17	2.69	1.25	2.30	1.16	2.43	1.19	13.07	6.22
	5	3.28	1.71	3.62	1.47	2.86	1.22	2.68	1.11	2.84	1.21	15.28	6.72
	6	3.13	1.65	3.43	1.58	3.39	1.52	2.49	1.25	2.86	1.40	15.30	7.40
	Ave.	3.26	1.62	3.32	1.40	2.98	1.30	2.54	1.20	2.74	1.28	14.83	6.82
6	1	3.15	1.59	2.99	1.32	2.75	1.31	2.97	1.39	2.78	1.30	14.64	7.01
	2	3.44	1.58	3.47	1.40	2.99	1.22	2.72	1.21	2.66	1.18	15.28	6.59
	3	3.60	1.64	3.67	1.42	2.79	1.11	2.50	1.09	2.56	1.13	15.12	6.39
	4	3.40	1.48	3.41	1.21	2.74	1.11	2.67	1.10	2.75	1.16	14.97	6.00
	5	2.74	1.38	4.18	2.18	3.50	1.67	2.78	1.16	3.70	1.52	16.90	7.97
	6	3.20	1.61	3.60	1.70	4.08	1.86	3.71	1.43	3.18	1.42	17.77	8.02
	Ave.	3.26	1.55	3.55	1.54	3.14	1.38	2.89	1.23	2.94	1.28	15.78	7.00
7	1	3.26	1.67	2.80	1.29	2.75	1.42	2.53	1.34	2.82	1.53	14.16	7.25
	2	2.96	1.41	3.74	1.50	3.05	1.31	2.41	1.15	2.35	1.11	14.51	6.48
	3	3.41	1.76	3.23	1.43	3.02	1.51	2.79	1.28	2.54	1.27	15.09	7.25
	4	2.79	1.43	3.40	1.58	3.10	1.43	3.61	1.82	3.95	1.80	16.75	8.06
	5	2.95	1.47	3.67	1.51	3.00	1.21	2.78	1.11	2.74	1.14	15.12	6.44
	6	3.22	1.69	3.69	1.70	3.14	1.40	3.09	1.27	3.51	1.47	16.65	7.53
	Ave.	3.10	1.57	3.42	1.50	3.01	1.38	2.87	1.33	2.98	1.39	15.38	7.17
8	1	3.19	1.69	3.44	1.53	2.83	1.35	2.45	1.22	2.69	1.42	14.60	7.21
	2	3.08	1.56	2.73	1.32	2.59	1.20	2.62	1.27	2.62	1.32	13.64	6.03
	3	3.30	1.57	2.80	1.24	2.52	1.17	2.43	1.17	2.83	1.33	13.88	6.46
	4	2.86	1.38	2.82	1.23	2.55	1.17	2.46	1.12	3.05	1.33	13.74	6.43
	5	3.29	1.64	3.96	1.56	3.14	1.27	2.68	1.19	2.80	1.29	15.87	6.95
	6	3.19	1.47	3.57	1.51	2.64	1.35	2.60	1.07	2.74	1.23	15.74	6.63
	Ave.	3.15	1.55	3.22	1.40	2.71	1.25	2.54	1.17	2.79	1.32	14.58	6.62

APPENDIX 4: SUMMARY AND ANALYSIS OF AVAILABLE MOISTURE TO A 4 FOOT DEPTH (INCHES OF WATER) 1968-74

	Treatment							
Year	1	2	3	4	5	6	7	8
1968	4.67	5.61	4.74	4.91	4.82	4.71	4.61	4.52
1969	5.46	6.39	6.24	5.67	5.85	5.93	5.61	5.90
1970	4.49	4.86	4.52	4.74	4.75	4.68	4.04	4.28
1971	3.07	4.80	4.46	2.31	3.70	3.83	3.28	4.30
1972	5.33	5.59	5.63	5.40	5.27	5.13	5.96	5.48
1973	3.49	5.33	4.55	2.95	4.16	4.32	4.66	4.19
1974	4.16	4.49	4.46	4.53	4.58	4.68	4.45	3.82
Means	4.38 a	5.30 c	4.94 bc	4.36 a	4.73 ab	4.75 ab	4.66 ab	4.64 ab

Source	Degrees of Freedom	Sum of Squares	Square Mean	F-Value
TREAT	7	4.46	0.638	3.87**
YEAR	6	26.63	4.44	26.97
ERROR	42	6.91	0.165	
TOTAL	55	38.01		

a,b,c Means with a common letter below are not significantly different at the 5 percent probability level.

*, ** Significant at the 5 and 1 percent levels respectively.

APPENDIX 5: SUMMARY AND ANALYSIS OF AVAILABLE MOISTURE TO A 5 FOOT DEPTH (INCHES OF WATER) 1969-74

	Treatment							
Year	1	2	3	4	5	6	7	8
1969	6.37	7.46	7.45	6.75	6.77	7.38	6.62	6.73
1970	5.44	5.94	5.52	5.55	5.65	5.70	5.08	5.40
1971	3.37	5.40	5.07	2.75	4.03	4.55	4.11	4.58
1972	6.20	6.76	6.53	6.07	6.23	5.74	6.55	5.81
1973	3.94	6.01	5.12	3.40	4.46	5.05	4.70	4.55
1974	4.97	5.75	5.60	5.19	5.75	5.75	5.59	4.74
Means	5.04 a	6.22 d	5.88 cd	4.95 a	5.48 abc	5.70 bc	5.44 abc	5.30 ab

Source	Degrees of Freedom	Sum of Squares	Square Mean	F-Value
TREAT	7	7.50	1.07	6.41**
YEAR	5	39.60	7.92	47.37
ERROR	35	5.85	0.167	
TOTAL	47	52.95		

a,b,c,d Means with a common letter below are not significantly different at the 5 percent probability level.

*, ** Significant at the 5 and 1 percent levels respectively.

APPENDIX 6: MEAN PERCENTAGES OF PRECIPITATION CONSERVED IN THE 5 FOOT SOIL PROFILE FOR EACH INTERVAL OF THE FALLOW CYCLE (1968-74)

	Treatment							
Interval	1	2	3	4	5	6	7	8
First Winter Period								
1968-69	66	66	72	70	66	65	62	68
1969-70	20	33	27	20	21	31	17	27
1970-71	33	42	32	37	20	25	41	40
1971-72	43	57	48	40	42	44	48	49
1972-73	61	56	56	43	66	71	76	56
Ave.	45	51	47	44	43	47	49	48
Summerfallow season								
1969	-16	-16	-23	-13	-14	-10	-17	-17
1970	11	19	22	12	23	22	16	18
1971	13	13	8	- 6	22	17	7	6
1972	11	1	- 4	8	8	10	- 1	6
1973	18	25	27	18	19	25	30	33
Ave.	7	8	6	4	12	13	14	9
Second Winter Period								
1969-70	4	16	11	7	4	7	7	13
1970-71	15	13	20	7	19	18	13	15
1971-72	21	22	27	32	25	16	27	19
1972-73	11	29	35	11	26	28	29	12
1973-74	15	15	19	19	20	15	16	11
Ave.	13	19	22	15	19	17	18	14
Overall								
1968-70	19	22	21	23	20	22	18	22
1969-71	15	21	23	12	18	20	16	22
1970-72	22	25	22	20	22	19	24	21
1971-73	26	32	29	24	28	30	28	27
1972-74	27	28	30	27	30	31	35	29
Overall Ave.	22	26	25	21	24	24	24	24

APPENDIX 7: NEUTRON SOIL MOISTURE DATA FROM THE FALLOW AND CROP SEASONS 1972-74

FIELD B
(FALLOW)
1972

Total Inches of Water per 6 Inch Depth

Date	Treat	Depth 9"	12"	18"	24"	30"	36"	42"	48"	54"	Total
Jun 20	1	.98[ab]	1.23	1.47	1.45	1.36	1.14[a]	.98[abc]	.99	1.04	10.64
	2	1.15[c]	1.32	1.57	1.57	1.52	1.40[b]	1.21[bc]	1.08	1.13	11.96
	3	1.01[ab]	1.31	1.59	1.55	1.39	1.14[a]	.89[a]	.87	.93	10.68
	4	.94[a]	1.25	1.53	1.55	1.32	1.07[a]	.92[a]	.95	1.01	10.44
	5	1.08[bc]	1.31	1.55	1.44	1.31	1.07[a]	.89[a]	.91	.98	10.54
	6	1.10[bc]	1.28	1.61	1.50	1.36	1.16[a]	.97[ab]	.93	1.03	10.94
	7	1.01[ab]	1.36	1.72	1.65	1.53	1.39[b]	1.23[c]	1.08	1.05	12.02
	8	1.10[bc]	1.30	1.58	1.52	1.36	1.23[ab]	1.10[abc]	1.07	1.11	11.36
Jul 6	1	.99[ab]	1.23	1.48	1.43	1.33	1.15[ab]	.97[ab]	.98	1.03	10.68
	2	1.14[e]	1.29	1.56	1.55	1.50	1.36[c]	1.19[bc]	1.08	1.14	11.80
	3	1.03[abcd]	1.33	1.61	1.57	1.40	1.18[abc]	.91[a]	.88	.93	10.84
	4	.95[a]	1.22	1.50	1.48	1.31	1.07[a]	.94[a]	.95	1.00	10.42
	5	1.09[bcde]	1.31	1.56	1.52	1.30	1.11[a]	.92[a]	.91	.98	10.69
	6	1.13[de]	1.32	1.59	1.54	1.39	1.20[abc]	1.01[abc]	.97	1.05	11.20
	7	1.02[abcd]	1.31	1.67	1.61	1.49	1.34[bc]	1.22[c]	1.08	1.02	11.76
	8	1.12[cde]	1.31	1.57	1.51	1.34	1.24[abc]	1.12[abc]	1.08	1.12	11.41
Jul 26	1	1.05[a]	1.25	1.42	1.44	1.35	1.17[abc]	1.01[ab]	.99	1.03	10.72
	2	1.24[c]	1.41	1.63	1.62	1.55	1.43[d]	1.27[c]	1.11	1.15	12.41
	3	1.12[ab]	1.40	1.62	1.60	1.43	1.21[abc]	.96[a]	.89	.92	11.15
	4	1.03[a]	1.26	1.52	1.51	1.30	1.06[a]	.94[a]	.98	1.00	10.59
	5	1.19[bc]	1.41	1.62	1.52	1.36	1.12[ab]	.95[a]	.92	.98	11.07
	6	1.20[bc]	1.40	1.69	1.58	1.45	1.24[abcd]	1.04[abc]	.98	1.04	11.62
	7	1.10[ab]	1.36	1.69	1.58	1.48	1.34[cd]	1.22[bc]	1.09	1.02	11.88
	8	1.20[bc]	1.40	1.66	1.57	1.40	1.30[bcd]	1.15[abc]	1.11	1.12	11.94

a,b,c,d,e Column means with a common letter in the superscript are not significantly different at the 5 percent probability level.

APPENDIX 7: CONTINUED

FIELD B
(FALLOW)
1972

Total Inches of Water per 6 Inch Depth

Date	Treat	Depth 9"	12"	18"	24"	30"	36"	42"	48"	54"	Total
Aug 16	1	1.00^{b}	1.24	1.49	1.44	1.38	1.25^{bc}	1.05	1.01	1.04	10.89
	2	1.15^{c}	1.35	1.58	1.57	1.54	1.42^{d}	1.33	1.16	1.16	12.27
	3	1.00^{b}	1.41	1.60	1.57	1.44	1.27^{bcd}	1.07	.92	.94	11.22
	4	$.89^{a}$	1.21	1.50	1.48	1.28	1.08^{a}	.97	.98	1.01	10.40
	5	1.07^{bc}	1.34	1.57	1.46	1.38	1.20^{ab}	1.03	.95	.99	10.99
	6	1.11^{bc}	1.26	1.65	1.55	1.44	1.33^{bcd}	1.16	1.02	1.06	11.58
	7	1.03^{b}	1.35	1.68	1.62	1.50	1.38^{cd}	1.28	1.14	1.06	12.04
	8	1.11^{bc}	1.32	1.61	1.54	1.41	1.38^{cd}	1.19	1.15	1.16	11.86
Sept 13	1	$.78^{a}$	1.13^{a}	1.43	1.40	1.33^{a}	1.23^{bc}	1.06	1.02	1.04	10.43
	2	1.11^{d}	1.33^{b}	1.54	1.55	1.52^{c}	1.42^{d}	1.32	1.19	1.21	12.20
	3	$.95^{b}$	1.27^{b}	1.57	1.54	1.41^{abc}	1.23^{bc}	1.11	.96	.95	10.99
	4	$.72^{a}$	1.09^{a}	1.47	1.49	1.28^{a}	1.08^{a}	.99	.99	1.03	10.14
	5	1.05^{bcd}	1.29^{b}	1.53	1.44	1.36^{ab}	1.20^{b}	1.09	.96	.99	10.91
	6	1.07^{cd}	1.28^{b}	1.61	1.53	1.38^{ab}	1.34^{cd}	1.21	1.06	1.06	11.54
	7	$.99^{bc}$	1.31^{b}	1.64	1.57	1.48^{bc}	1.35^{cd}	1.28	1.17	1.08	11.87
	8	1.05^{bcd}	1.26^{b}	1.54	1.46	1.36^{ab}	1.35^{cd}	1.17	1.11	1.12	11.44
Oct 19	1	$.92^{a}$	1.18^{ab}	1.43	1.41	1.35^{ab}	1.24^{bc}	1.11	1.04	1.04	10.71
	2	1.14^{c}	1.36^{c}	1.57	1.57	1.54^{c}	1.45^{d}	1.33	1.22	1.20	12.38
	3	1.03^{b}	1.32^{bc}	1.59	1.56	1.42^{abc}	1.24^{bc}	1.10	.99	.96	11.21
	4	$.85^{a}$	1.14^{a}	1.47	1.48	1.27^{a}	1.07^{a}	1.00	1.00	1.02	10.30
	5	1.09^{bc}	1.33^{bc}	1.54	1.45	1.37^{ab}	1.22^{b}	1.11	1.00	1.01	11.12
	6	$.83^{a}$	1.18^{ab}	1.61	1.56	1.46^{bc}	1.37^{bcd}	1.24	1.08	1.08	11.41
	7	1.05^{bc}	1.34^{c}	1.66	1.56	1.45^{bc}	1.34^{cd}	1.25	1.16	1.08	11.89
	8	$.89^{a}$	1.21^{abc}	1.57	1.49	1.38^{b}	1.37^{cd}	1.21	1.14	1.14	11.40

APPENDIX 7: CONTINUED

FIELD A
(CROP)
1972

Total Inches of Water per 6 Inch Depth

Date	Treat	Depth 9"	12"	18"	24"	30"	36"	42"	48"	54"	Total
Jun 14	1	.96	1.22	1.65	1.64	1.60	1.50	1.44	1.42[ab]	1.33[a]	12.75
	2	.99	1.24	1.65	1.66	1.49	1.48	1.49	1.46[bc]	1.47[ab]	12.93
	3	.96	1.23	1.70	1.83	1.74	1.63	1.56	1.57[c]	1.49[ab]	13.72
	4	1.00	1.25	1.66	1.64	1.49	1.44	1.43	1.33[a]	1.33[a]	12.57
	5	.97	1.23	1.62	1.72	1.66	1.58	1.55	1.50[bc]	1.54[b]	13.37
	6	.95	1.19	1.58	1.63	1.50	1.46	1.39	1.33[a]	1.34[a]	12.38
	7	1.02	1.24	1.68	1.74	1.62	1.55	1.54	1.47[bc]	1.37[a]	13.24
	8	.93	1.14	1.54	1.69	1.68	1.58	1.52	1.46[bc]	1.48[ab]	13.03
Jul 13	1	.73	.89	1.15	1.16	1.14	1.17	1.25	1.29[ab]	1.25	10.04
	2	.75	.91	1.12	1.15	1.05	1.10	1.24	1.30[ab]	1.36	9.98
	3	.75	.91	1.25	1.36	1.37	1.38	1.41	1.47[c]	1.42	11.31
	4	.78	.93	1.17	1.20	1.13	1.19	1.25	1.19[a]	1.26	10.10
	5	.73	.90	1.09	1.20	1.24	1.24	1.31	1.34[abc]	1.45	10.52
	6	.73	.86	1.06	1.13	1.11	1.13	1.16	1.20[ab]	1.26	9.64
	7	.76	.91	1.16	1.23	1.24	1.31	1.38	1.35[bc]	1.29	10.64
	8	.72	.86	1.03	1.10	1.17	1.23	1.27	1.33[abc]	1.41	10.12
Aug 1	1	.69	.82	1.04	1.04	1.01	1.00	1.07	1.12	1.14	8.92
	2	.72	.85	1.02	1.04	.94	.95	1.02	1.08	1.22	8.84
	3	.71	.87	1.12	1.22	1.20	1.18	1.21	1.32	1.32	10.14
	4	.76	.89	1.08	1.10	1.00	1.03	1.09	1.06	1.15	9.18
	5	.76	.86	1.02	1.09	1.10	1.09	1.13	1.18	1.31	9.54
	6	.71	.83	.98	1.02	1.00	.99	1.01	1.06	1.13	8.74
	7	.72	.87	1.06	1.10	1.09	1.16	1.21	1.24	1.21	9.59
	8	.69	.80	.96	1.02	1.03	1.06	1.06	1.14	1.27	9.04

APPENDIX 7: CONTINUED

FIELD A
(CROP)
1972

Total Inches of Water per 6 Inch Depth

Date	Treat	9"	12"	18"	24"	30"	36"	42"	48"	54"	Total
		Depth									
Aug 30	1	.60	.75	.92	.92	.89	.89	.93	.97	1.00	7.87
	2	.64	.78	.92	.92	.85	.86	.89	.93	1.04	7.82
	3	.60	.79	1.03	1.09	1.08	1.04	1.06	1.14	1.19	9.03
	4	.67	.81	.98	.98	.93	.94	.97	.96	1.03	8.26
	5	.69	.79	.93	.97	.97	.97	1.01	1.04	1.16	8.53
	6	.63	.77	.92	.93	.91	.90	.91	.94	1.01	7.92
	7	.70	.78	.95	.97	.95	1.01	1.05	1.07	1.09	8.56
	8	.75	.80	.90	.93	.95	.93	.94	1.01	1.15	8.24
Oct 20	1	.76	.81	.91	.92	.89	.88	.92	.95	.99	8.03
	2	.73	.83	.92	.91	.84	.82	.90	.93	1.03	7.90
	3	.79	.89	1.04	1.08	1.06	1.05	1.06	1.15	1.19	9.31
	4	.78	.86	.99	.97	.90	.94	.94	.94	1.03	8.34
	5	.71	.89	1.00	1.00	.97	.97	1.02	1.05	1.16	8.76
	6	.73	.83	.97	.91	.90	.90	.90	.92	.98	8.04
	7	.79	.87	.94	.96	.96	1.01	1.04	1.08	1.07	8.72
	8	.75	.80	.90	.93	.96	.93	.94	1.01	1.15	8.35

APPENDIX 7: CONTINUED

FIELD A (FALLOW) 1973

Total Inches of Water per 6 Inch Depth

Date	Treat.	9"	12"	18"	24"	30"	36"	42"	48"	54"	Total
		Depth									
May 31	1	.74[d]	1.03	1.46	1.39	1.19	1.01	.97	.98	1.00	9.77
	2	1.06[ab]	1.15	1.53	1.39	1.16	1.09	1.06	1.05	1.11	10.60
	3	.82[cd]	1.18	1.58	1.54	1.37	1.21	1.16	1.21	1.22	11.30
	4	.87[cd]	1.16	1.50	1.40	1.19	1.15	1.10	1.05	1.11	10.53
	5	.95[bc]	1.19	1.43	1.41	1.23	1.15	1.13	1.12	1.20	10.81
	6	.99[abc]	1.22	1.53	1.45	1.30	1.20	1.10	1.06	1.12	10.97
	7	.81[cd]	1.16	1.56	1.47	1.26	1.17	1.16	1.17	1.13	10.89
	8	1.15[a]	1.28	1.48	1.49	1.37	1.23	1.13	1.10	1.19	11.42
Jun 20	1	1.08	1.26	1.54	1.39	1.18	1.03	.97	.98	.99	10.42
	2	1.18	1.37	1.62	1.47	1.26	1.08	1.05	1.04	1.12	11.21
	3	1.14	1.41	1.69	1.60	1.39	1.23	1.18	1.21	1.25	12.09
	4	1.01	1.92	1.61	1.37	1.17	1.15	1.08	1.04	1.10	10.82
	5	1.15	1.37	1.58	1.47	1.27	1.18	1.13	1.12	1.20	11.42
	6	1.13	1.35	1.64	1.50	1.31	1.18	1.07	1.06	1.11	11.35
	7	1.04	1.35	1.63	1.49	1.25	1.16	1.17	1.14	1.12	11.34
	8	1.26	1.41	1.64	1.59	1.40	1.22	1.12	1.10	1.16	11.91
Jul 12	1	.96	1.27	1.58	1.47	1.33	1.18	1.07	1.02	1.04	10.93
	2	1.28	1.33	1.62	1.48	1.24	1.14	1.05	1.06	1.12	11.31
	3	1.03	1.32	1.64	1.61	1.42	1.24	1.18	1.21	1.24	11.88
	4	1.05	1.35	1.63	1.38	1.22	1.14	1.07	1.05	1.10	10.99
	5	1.06	1.32	1.59	1.53	1.33	1.19	1.15	1.14	1.21	11.52
	6	1.04	1.30	1.54	1.43	1.26	1.11	1.01	.99	1.06	10.75
	7	1.02	1.31	1.61	1.53	1.34	1.24	1.21	1.19	1.16	11.60
	8	1.17	1.34	1.58	1.60	1.50	1.30	1.12	1.13	1.18	11.92

APPENDIX 7: CONTINUED

FIELD A (FALLOW) 1973		Total Inches of Water per 6 Inch Depth									
		Depth									
Date	Treat	9"	12"	18"	24"	30"	36"	42"	48"	54"	Total
Jul 31	1	.78[c]	1.09	1.49	1.41	1.25	1.08	.98	.97	1.00	10.05
	2	1.08[a]	1.28	1.58	1.45	1.23	1.16	1.08	1.05	1.12	11.03
	3	.97[b]	1.26	1.61	1.59	1.41	1.24	1.17	1.22	1.22	11.69
	4	.86[bc]	1.22	1.56	1.45	1.24	1.15	1.11	1.05	1.43	10.79
	5	1.01[a]	1.26	1.53	1.49	1.34	1.20	1.16	1.14	1.21	11.36
	6	1.03[a]	1.29	1.56	1.47	1.32	1.21	1.11	1.07	1.10	11.16
	7	.99[ab]	1.27	1.57	1.51	1.34	1.25	1.20	1.19	1.15	11.46
	8	1.12[a]	1.28	1.54	1.56	1.46	1.31	1.16	1.11	1.18	11.73
Sept 10	1	1.04	1.21	1.47	1.37	1.25[ab]	1.09	1.01	.99	1.00	10.44
	2	1.19	1.36	1.58	1.42	1.19[b]	1.14	1.09	1.07	1.13	11.18
	3	1.15	1.39	1.65	1.61	1.44[a]	1.28	1.24	1.27	1.26	12.28
	4	1.06	1.32	1.56	1.41	1.21[b]	1.16	1.11	1.07	1.13	11.02
	5	1.17	1.38	1.55	1.49	1.32[ab]	1.21	1.15	1.14	1.21	11.61
	6	1.14	1.37	1.59	1.46	1.40[ab]	1.20	1.12	1.08	1.11	11.38
	7	1.08	1.34	1.62	1.55	1.39[ab]	1.30	1.26	1.22	1.16	11.92
	8	1.25	1.39	1.54	1.53	1.42[ab]	1.31	1.17	1.13	1.18	11.91
Oct 3	1	.91[c]	1.15	1.48	1.40	1.24	1.10	1.07	.98	1.00	10.27
	2	1.07[a]	1.29	1.57	1.43	1.22	1.15	1.11	1.05	1.12	11.01
	3	1.00[abc]	1.29	1.58	1.55	1.40	1.24	1.19	1.22	1.21	11.68
	4	.96[bc]	1.27	1.56	1.42	1.22	1.16	1.09	1.05	1.11	10.83
	5	1.00[abc]	1.24	1.52	1.48	1.33	1.21	1.15	1.14	1.20	11.27
	6	1.05[ab]	1.28	1.58	1.48	1.33	1.22	1.13	1.08	1.11	11.25
	7	1.01[abc]	1.29	1.59	1.52	1.33	1.28	1.23	1.18	1.15	11.57
	8	1.13[a]	1.27	1.53	1.55	1.46	1.32	1.17	1.14	1.18	11.73

APPENDIX 7: CONTINUED

FIELD B (CROP) 1973		Total Inches of Water per 6 Inch Depth									
		Depth									
Date	Treat	9"	12"	18"	24"	30"	36"	42"	48"	54"	Total
Mar 21	1	.94^{e}	1.22	1.42	1.40	1.27	1.17^{bcd}	1.09	1.05	1.06	10.65^{b}
	2	1.21^{a}	1.50	1.66	1.58	1.45	1.36^{a}	1.29	1.19	1.25	12.50^{a}
	3	1.06^{bcd}	1.42	1.65	1.57	1.34	1.18^{bcd}	1.10	1.04	1.00	11.37^{ab}
	4	.96de	1.27	1.55	1.45	1.21	1.05^{c}	1.02	1.04	1.04	10.60^{b}
	5	1.10^{b}	1.48	1.62	1.45	1.34	1.15^{cd}	1.11	1.06	1.03	11.33^{ab}
	6	.98^{cde}	1.26	1.72	1.53	1.36	1.27^{ab}	1.22	1.14	1.09	11.56^{ab}
	7	1.05^{bcd}	1.41	1.75	1.62	1.35	1.25^{abc}	1.20	1.17	1.10	11.91^{a}
	8	1.08^{bc}	1.41	1.72	1.47	1.32	1.32^{a}	1.19	1.13	1.13	11.76^{ab}
May 30	1	.85^{c}	1.16^{c}	1.42	1.36^{c}	1.32^{c}	1.23^{bc}	1.13^{bc}	1.08	1.08	10.63^{c}
	2	.99^{abc}	1.37^{ab}	1.64	1.63^{a}	1.58^{a}	1.48^{a}	1.41^{a}	1.30	1.33	12.73^{a}
	3	.96^{ab}	1.33^{ab}	1.62	1.56^{ab}	1.44^{abc}	1.29^{bc}	1.18^{bc}	1.10	1.03	11.51^{bcd}
	4	.86^{bc}	1.22^{bc}	1.55	1.51^{ab}	1.31^{c}	1.21^{c}	1.09^{c}	1.07	1.06	10.89^{cd}
	5	.99^{a}	1.38^{a}	1.59	1.46^{bc}	1.39^{bc}	1.25^{bc}	1.20^{bc}	1.18	1.05	11.48^{bcd}
	6	.86^{bc}	1.29^{ab}	1.64	1.56^{ab}	1.45^{abc}	1.38^{ab}	1.30^{ab}	1.17	1.14	11.79^{abc}
	7	.95^{abc}	1.35^{ab}	1.69	1.60^{ab}	1.48^{ab}	1.37^{ab}	1.31^{ab}	1.23	1.16	12.14^{ab}
	8	.91^{abc}	1.27^{ab}	1.56	1.46^{bc}	1.36^{bc}	1.34^{abc}	1.20^{bc}	1.14	1.16	11.39^{bcd}
Jun 21	1	.95	1.19	1.43	1.40	1.32^{bc}	1.25^{bc}	1.15	1.10	1.09^{b}	10.88^{cd}
	2	1.09	1.39	1.56	1.57	1.54^{a}	1.45^{a}	1.35	1.29	1.34^{a}	12.59^{a}
	3	.98	1.29	1.59	1.55	1.43^{abc}	1.28^{bc}	1.19	1.11	1.05^{b}	11.46^{bcd}
	4	.87	1.20	1.48	1.47	1.29^{c}	1.14^{c}	1.08	1.07	1.06^{b}	10.66^{d}
	5	1.03	1.36	1.56	1.46	1.40^{abc}	1.26^{bc}	1.23	1.13	1.07^{b}	11.51^{bcd}
	6	.92	1.25	1.65	1.55	1.45^{ab}	1.38^{ab}	1.31	1.18	1.15^{ab}	11.84^{abc}
	7	1.00	1.33	1.66	1.56	1.46^{ab}	1.36^{ab}	1.28	1.23	1.15^{ab}	12.02^{ab}
	8	.90	1.23	1.58	1.50	1.39^{abc}	1.39^{ab}	1.26	1.20	1.18^{ab}	11.51^{abcd}

APPENDIX 7: CONTINUED

FIELD B
(CROP)
1973

Total Inches of Water per 6 Inch Depth

Date	Treat	Depth 9"	12"	18"	24"	30"	36"	42"	48"	54"	Total
Jul 19	1	$.57^{b}$	$.72^{bc}$	.84	.86	.92	.97	1.03	1.06	1.07	8.03^{bc}
	2	$.59^{a}$	$.76^{ab}$	.87	.92	.99	1.05	1.11	1.13	1.22	8.62^{ab}
	3	$.58^{ab}$	$.76^{abc}$	.88	.93	.96	.96	1.01	1.05	1.04	8.17^{bc}
	4	$.56^{b}$	$.73^{bc}$	.85	.87	.87	.89	.99	1.06	1.05	7.86^{c}
	5	$.59^{a}$	$.75^{abc}$	.83	.86	.92	.94	1.05	1.05	1.06	8.06^{bc}
	6	$.56^{b}$	$.74^{abc}$	.92	.95	.97	1.05	1.13	1.12	1.12	8.56^{ab}
	7	$.61^{a}$	$.79^{a}$	.93	.96	1.01	1.11	1.18	1.19	1.17	8.95^{a}
	8	$.55^{b}$	$.71^{c}$	.85	.87	.89	1.00	1.04	1.11	1.14	8.15^{bc}
Aug 3	1	.55	.68	$.77^{b}$	.80	.82	.85	.90	.98	1.02	7.37
	2	.54	.71	$.81^{ab}$	.84	.86	.88	.91	.93	1.04	7.52
	3	.54	.70	$.82^{ab}$	.83	.87	.85	.87	.91	.96	7.34
	4	.51	.67	$.81^{ab}$	.80	.79	.78	.85	.97	1.02	7.20
	5	.56	.72	$.76^{b}$	.77	.81	.84	.88	.95	1.00	7.30
	6	.53	.71	$.85^{a}$	.86	.87	.92	.97	1.04	1.06	7.80
	7	.56	.71	$.83^{a}$	.84	.85	.91	.99	1.07	1.09	7.84
	8	.51	.66	$.79^{ab}$	.79	.79	.82	.87	.97	1.01	7.21
Aug 23	1	.47	.63	.76	.80	.82	.83	.88	.96	.99	7.14
	2	.54	.69	.79	.83	.84	.85	.85	.88	.98	7.25
	3	.51	.67	.80	.82	.84	.85	.87	.92	.99	7.26
	4	.51	.68	.80	.81	.79	.77	.83	.95	1.00	7.14
	5	.53	.67	.76	.79	.81	.78	.87	.91	.98	7.11
	6	.50	.70	.83	.85	.85	.87	.91	.96	1.03	7.51
	7	.54	.69	.82	.83	.82	.89	.95	1.03	1.03	7.60
	8	.49	.66	.77	.77	.78	.82	.83	.93	.96	7.01

APPENDIX 7: CONTINUED

FIELD A
(CRQP)
1974

Total Inches of Water per 6 Inch Depth

Date	Treat	Depth 9"	12"	18"	24"	30"	36"	42"	48"	54"	Total
May 7	1	1.13	1.42	1.75	1.69	1.65	1.52	1.28	1.15	1.07	12.65
	2	1.22	1.47	1.76	1.67	1.54	1.55	1.52	1.46	1.44	13.64
	3	1.21	1.53	1.84	1.86	1.77	1.63	1.56	1.50	1.42	14.32
	4	1.19	1.52	1.77	1.68	1.56	1.55	1.46	1.25	1.26	13.24
	5	1.21	1.47	1.78	1.77	1.70	1.62	1.55	1.40	1.36	13.87
	6	1.25	1.50	1.79	1.70	1.62	1.56	1.48	1.39	1.36	13.65
	7	1.22	1.53	1.85	1.83	1.70	1.64	1.55	1.41	1.30	14.03
	8	1.24	1.46	1.71	1.75	1.72	1.62	1.55	1.43	1.35	13.82
Jun 5	1	1.06	1.37	1.69	1.64	1.62	1.50	1.42	1.36	1.17[b]	12.82
	2	1.17	1.45	1.75	1.62	1.47	1.49	1.53	1.49	1.42[a]	13.39
	3	1.07	1.42	1.80	1.81	1.71	1.58	1.53	1.53	1.47[a]	13.92
	4	1.43	1.47	1.70	1.58	1.47	1.47	1.38	1.29	1.34[ab]	12.86
	5	1.11	1.42	1.72	1.70	1.63	1.57	1.51	1.55	1.48[a]	13.67
	6	1.10	1.33	1.65	1.56	1.51	1.47	1.38	1.37	1.38[a]	12.76
	7	1.15	1.47	1.75	1.72	1.58	1.56	1.53	1.44	1.34[ab]	13.55
	8	1.12	1.41	1.69	1.69	1.63	1.55	1.50	1.44	1.48[a]	13.51
Jul 5	1	.62	.78	1.12	1.26	1.24	1.28	1.38	1.32[bc]	1.31	10.30
	2	.69	.84	1.16	1.24	1.14	1.23	1.33	1.32[bc]	1.37	10.32
	3	.67	.80	1.18	1.41	1.44	1.47	1.43	1.48[a]	1.43	11.30
	4	.67	.79	1.12	1.21	1.13	1.20	1.30	1.23[c]	1.28	9.92
	5	.61	.77	1.07	1.23	1.31	1.36	1.39	1.39[ab]	1.45	10.59
	6	.68	.79	1.09	1.21	1.22	1.37	1.31	1.28[bc]	1.32	10.27
	7	.69	.86	1.17	1.30	1.27	1.36	1.43	1.40[ab]	1.32	10.80
	8	.67	.82	1.05	1.16	1.25	1.36	1.39	1.37[ab]	1.41	10.50

APPENDIX 7: CONTINUED

FIELD A (CROP) 1974

Total Inches of Water per 6 Inch Depth

Date	Treat	Depth 9"	12"	18"	24"	30"	36"	42"	48"	54"	Total
Jul 17	1	.56	.77[bcd]	1.11	1.17	1.13	1.13	1.19	1.25[bc]	1.26	9.57
	2	.64	.82[a]	1.11	1.16	1.02	1.07	1.18	1.25[bc]	1.33	9.58
	3	.57	.76[cd]	1.16	1.31	1.31	1.33	1.36	1.44[a]	1.39	10.63
	4	.62	.80[abc]	1.10	1.13	1.03	1.04	1.14	1.15[c]	1.25	9.26
	5	.56	.75[d]	1.02	1.12	1.14	1.18	1.27	1.31[abc]	1.39	9.73
	6	.62	.79[abcd]	1.07	1.12	1.11	1.12	1.17	1.19[bc]	1.28	9.46
	7	.62	.81[ab]	1.13	1.20	1.16	1.22	1.33	1.35[ab]	1.28	10.10
	8	.62	.79[abc]	1.03	1.10	1.14	1.20	1.24	1.30[abc]	1.35	9.77
Jul 30	1	.48[b]	.69	.92	1.01	.97	.95	1.01	1.09	1.15	8.27
	2	.56[a]	.73	.91	.98	.89	.88	.98	1.08	1.21	8.23
	3	.47[a]	.69	.98	1.11	1.10	1.10	1.15	1.27	1.28	9.15
	4	.56[b]	.74	.94	.98	.91	.90	.97	1.00	1.14	8.13
	[illegible]	[illegible]	.67	.89	.96	.97	.98	1.08	1.15	1.29	8.45
	[illegible]	[illegible]	.72	.91	.96	.94	.94	.96	1.03	1.12	8.10
	[illegible]	[illegible]	.72	.96	1.03	1.01	1.03	1.15	1.22	1.20	8.83
	[illegible]	[illegible]	.72	.90	.98	.98	1.00	1.04	1.15	1.28	8.55
Aug 14	1	[illegible]	.76	.88	.95[b]	.91	.90	.91	1.00	1.08	8.17
	2	[illegible]	.77	.89	.91[b]	.86	.85	.91	1.01	1.17	8.12
	3	[illegible]	.78	.96	1.08[a]	1.07	1.07	1.08	1.21	1.25	9.29
	4	.75	.75	.89	.93[b]	.87	.86	.91	.92	1.05	7.93
	5	.75	.76	.86	.91[b]	.92	.93	.99	1.07	1.21	8.40
	6	.72	.75	.87	.92[b]	.89	.89	.89	.94	1.05	7.92
	7	.77	.77	.91	.97[ab]	.95	.97	1.09	1.15	1.17	8.77
	8	.80	.77	.88	.94[b]	.94	.95	.98	1.08	1.22	8.55

APPENDIX 7: CONTINUED

FIELD B
(FALLOW)
1974

Total Inches of Water per 6 Inch Depth

Date	Treat	Depth 9"	12"	18"	24"	30"	36"	42"	48"	54"	Total
May 28	1	1.13	1.35^{c}	1.53	1.47	1.28	1.00	.88	.96	.98	10.58
	2	1.09	1.43^{abc}	1.62	1.58	1.52	1.34	1.01	.88	.97	11.43
	3	1.07	1.47^{abc}	1.65	1.56	1.38	1.07	.86	.87	.90	10.82
	4	1.03	1.37^{bc}	1.62	1.52	1.25	.95	.90	.93	.96	10.53
	5	1.21	1.56^{a}	1.67	1.53	1.48	1.27	1.09	.94	.99	11.75
	6	1.19	1.50^{abc}	1.75	1.62	1.51	1.31	1.21	1.08	1.04	11.20
	7	1.13	1.52^{ab}	1.73	1.57	1.41	1.18	.99	1.00	.97	11.49
	8	1.06	1.41^{bc}	1.67	1.56	1.46	1.37	1.12	1.11	1.11	11.85
June 26	1	.71	$.94^{d}$	1.42	1.47	1.42	1.29^{bc}	1.09^{bc}	.95	.99	10.28^{bc}
	2	.82	1.02^{abcd}	1.51	1.59	1.55	1.47^{a}	1.32^{ab}	1.18	.99	11.46^{bc}
	3	.73	$.99^{bcd}$	1.54	1.59	1.49	1.34^{abc}	1.11^{bc}	.94	.91	10.64^{c}
	4	.79	1.08^{ab}	1.53	1.59	1.45	1.20^{c}	1.00^{c}	.95	1.00	10.58^{bc}
	5	.91	1.10^{a}	1.58	1.59	1.48	1.42^{ab}	1.24^{abc}	1.13	1.05	11.49^{ab}
	6	.82	1.07^{abc}	1.58	1.63	1.56	1.45^{ab}	1.38^{a}	1.20	1.10	11.78^{ab}
	7	.80	1.02^{abcd}	1.63	1.61	1.50	1.32^{abc}	1.18^{abc}	1.03	1.01	11.08^{bc}
	8	.78	$.98^{cd}$	1.51	1.59	1.48	1.42^{ab}	1.35^{ab}	1.15	1.16	11.42^{a}
Jul 16	1	$.77^{d}$	1.01^{c}	1.43	1.43	1.39	1.26^{bc}	1.10	1.00	1.02	10.40
	2	$.90^{abc}$	1.11^{ab}	1.52	1.55	1.52	1.43^{a}	1.29	1.08	1.01	11.40
	3	$.86^{bcd}$	1.17^{a}	1.62	1.60	1.49	1.32^{abc}	1.13	.98	.97	11.13
	4	$.81^{cd}$	1.07^{abc}	1.50	1.56	1.39	1.17^{c}	1.02	.99	1.01	10.52
	5	1.00^{a}	1.20^{a}	1.59	1.51	1.47	1.38^{ab}	1.21	1.11	1.06	11.53
	6	$.94^{ab}$	1.15^{ab}	1.60	1.60	1.51	1.43^{a}	1.27	1.17	1.11	11.79
	7	$.91^{abc}$	1.16^{ab}	1.66	1.57	1.47	1.33^{ab}	1.17	1.05	1.02	11.34
	8	$.91^{abc}$	1.11^{ab}	1.58	1.58	1.45	1.44^{a}	1.32	1.17	1.17	11.72

APPENDIX 7: CONTINUED

FIELD B
(FALLOW)
1974

Total Inches of Water per 6 Inch Depth

Date	Treat	Depth 9"	12"	18"	24"	30"	36"	42"	48"	54"	Total
Jul 31	1	.70[c]	1.03[c]	1.40	1.42	1.38	1.25	1.08	.99	1.02	10.27
	2	.87[ab]	1.12[abc]	1.51	1.54	1.51	1.41	1.30	1.09	1.05	11.40
	3	.81[abc]	1.14[ab]	1.56	1.57	1.49	1.29	1.13	.98	.94	10.90
	4	.76[bc]	1.06[bc]	1.47	1.54	1.39	1.15	1.02	1.00	1.02	10.40
	5	.93[a]	1.20[a]	1.56	1.53	1.46	1.36	1.21	1.10	1.07	11.43
	6	.88[ab]	1.15[ab]	1.58	1.51	1.47	1.36	1.23	1.15	1.11	11.44
	7	.87[ab]	1.15[ab]	1.65	1.61	1.49	1.35	1.29	1.16	1.18	11.76
	8	.81[abc]	1.06[bc]	1.51	1.54	1.44	1.41	1.30	1.16	1.16	11.40
Aug 22	1	.96	1.07[d]	1.48	1.41	1.31	1.21[bc]	1.11[bc]	.99	1.02	10.57[c]
	2	1.01	1.20[abc]	1.55	1.60	1.54	1.44[a]	1.32[a]	1.16	1.06	11.90[a]
	3	.98	1.23[abc]	1.58	1.63	1.51	1.32[ab]	1.15[abc]	1.05	.94	11.38[abc]
	4	.98	1.13[cd]	1.53	1.60	1.41	1.18[c]	1.07[c]	1.02	1.04	10.96[bc]
	5	1.10	1.29[a]	1.63	1.58	1.47	1.38[a]	1.24[abc]	1.15	1.07	11.92[a]
	6	1.07	1.26[ab]	1.66	1.62	1.52	1.41[a]	1.29[ab]	1.17	1.12	12.11[a]
	7	1.01	1.21[abc]	1.65	1.59	1.47	1.32[abc]	1.20[abc]	1.08	1.02	11.55[ab]
	8	.99	1.17[bcd]	1.56	1.60	1.46	1.42[a]	1.31[a]	1.18	1.17	11.85[a]
Sept 25	1	.85	1.04	1.39	1.41	1.36	1.26	1.16	1.03	1.02	10.54
	2	.87	1.14	1.52	1.54	1.53	1.40	1.32	1.20	1.13	11.65
	3	.86	1.02	1.47	1.56	1.49	1.40	1.27	1.24	1.04	11.35
	4	.77	1.08	1.55	1.57	1.39	1.19	1.10	1.05	1.04	10.73
	5	.96	1.19	1.56	1.53	1.45	1.36	1.24	1.15	1.10	11.55
	6	.90	1.15	1.57	1.56	1.48	1.40	1.29	1.18	1.14	11.67
	7	.89	1.17	1.64	1.58	1.45	1.33	1.23	1.12	1.03	11.44
	8	.83	1.09	1.53	1.54	1.44	1.39	1.31	1.20	1.18	11.51

APPENDIX 8: MEAN NITRATE-NITROGEN LEVELS IN THE SOIL PRIOR TO PRESEEDING TILLAGE OF EACH YEAR (LB/AC)

Depth (in.)	Treatment 1	2	3	4	5	6	7	8	
				FIELD A (1972)					
0-6	20 ab	7 d	13 bcd	16 bc	10 cd	14 bcd	27 c	11 cd	
6-12	19 a	8 c	13 bc	16 ab	9 c	15 ab	19 a	16 ab	
12-24	29	25	27	32	29	33	33	32	D.N.S.
Total	68 ab	41 d	53 bcd	63 bc	49 cd	62 bc	79 a	59 bc	
				FIELD B (1973)					
0-6	42 a	23 c	32 b	28 b	28 b	31 b	39 a	31 b	
6-12	26 de	27 cde	31 abc	24 de	32 a	24 e	28 bcd	32 ab	
12-24	30 b	37 a	32 ab	23 c	33 ab	30 b	28 b	33 ab	
Total	98 a	87 bc	95 ab	75 d	93 ab	85 c	96 a	96 a	
				FIELD A (1974)					
0-6	9	8	6	9	8	10	11	13	D.N.S.
6-12	12 ab	8 bc	7 c	12 a	8 c	12 a	6 c	13 a	
12-24	45 a	32 bc	36 abc	38 abc	38 abc	42 ab	30 c	44 a	
Total	66 ab	49 c	49 c	59 abc	54 bc	64 ab	47 c	70 a	

a,b,c,d,e, Means with a common letter below in rows are not significantly different at the 5 percent probability level.

APPENDIX 9: SUMMARY AND ANALYSIS OF MEAN MATURE PLANT HEIGHTS (INCHES).

	Treatment							
Year	1	2	3	4	5	6	7	8
1968	29.0	29.9	28.2	29.6	29.0	29.4	29.3	30.3
1969	39.2	39.7	41.2	41.4	40.2	40.1	39.8	41.4
1970	26.6	27.8	26.4	26.8	27.1	26.6	27.2	28.2
1971	29.4	32.5	31.3	31.2	31.2	31.8	31.0	32.7
1972	30.6	30.5	29.8	29.6	30.1	30.5	30.4	31.6
1973	19.3	23.4	23.0	20.5	22.6	21.6	21.0	21.7
1974	23.0	22.6	22.4	22.6	22.4	22.6	23.1	22.9
7-yr mean	28.2 a	29.5 bc	28.9 ab	28.8 ab	28.9 ab	28.9 ab	28.8 ab	29.8 c

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value
TREAT	7	12.0	1.71	3.25**
YEAR	6	1875	312.5	593
ERROR	42	22.1	0.527	
TOTAL	55	1909		

a,b,c Means with a common letter below are not significantly different at the 5 percent probability level.

** Significant at the 1 percent probability level.

APPENDIX 10: SUMMARY AND ANALYSIS OF MEAN SPRING WHEAT YIELDS (BUS/AC)

Year	Treatment 1	2	3	4	5	6	7	8
1968	26.9	28.5	22.8	26.1	27.9	29.3	27.1	32.3
1969	39.7	36.6	37.1	37.3	36.4	38.1	36.2	37.9
1970	21.8	22.6	20.4	21.0	21.8	21.4	21.8	25.6
1971	22.5	30.6	28.7	26.1	27.6	28.9	26.6	31.4
1972	33.3	29.9	29.4	28.1	30.8	31.8	31.7	34.7
1973	14.6	22.6	19.9	17.9	21.8	21.0	18.9	24.4
1974	20.8	23.0	20.4	19.0	20.8	20.2	22.0	23.7
7-yr mean	25.6 a	27.7 b	25.5 a	25.1 a	26.7 ab	27.2 ab	26.3 ab	30.0 c
S.D. ±	8.4	5.3	6.5	6.7	5.7	6.7	6.1	5.5

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F-Value
TREAT	7	121.5	17.4	5.78**
YEAR	6	1853	309	102.8
ERROR	42	126.1	3.00	
TOTAL	55	2101		

a,b,c Means with a common letter below are not significantly different at the 5 percent probability level.

S.D. Standard deviation from means.

** Significant at the 1 percent probability level.

APPENDIX 11: SUMMARY AND ANALYSIS OF MEAN MOISTURE DEPLETION FROM 5 FOOT SOIL PROFILE DURING GROWING SEASON (1969-74)

Crop Year	Treatment 1	2	3	4	5	6	7	8
1969	5.96	6.14	6.82	6.41	6.28	6.65	5.57	6.27
1970	5.83	6.49	5.51	5.51	6.11	5.85	5.56	5.88
1971	4.12	5.32	5.21	3.72	4.70	4.95	4.58	5.02
1972	6.39	6.49	6.88	6.12	6.45	6.05	7.94	6.53
1973	4.28	5.71	5.13	3.86	5.02	5.23	4.98	4.72
1974	4.68	5.54	5.34	5.06	5.33	5.69	5.57	5.11
6-yr mean	5.22 ab	5.95 c	5.82 c	5.11 a	5.65 bc	5.74 bc	5.67 bc	5.61 bc

Source	Degrees of Freedom	Sum of Squares	Square Mean	F-Value
TREAT	7	3.44	0.49	3.07*
YEAR	5	23.72	4.74	29.67
ERROR	35	5.60	0.16	
TOTAL	47	32.76		

a,b,c Means with a common letter below are not significantly different at the 5 percent probability level.

* Significant at the 5 percent probability level.

GLOSSARY[1]

Available water: the portion of water in a soil that can be readily absorbed by plant roots. Normally considered to be that water held in the soil against a pressure of up to 15 bars.

Bulk density, soil: the mass of dry soil per unit bulk volume. The bulk volume is determined before drying to constant weight at 105°C.

Chiseling: the breaking or shattering of compact soil or sub-soil layers by use of a chisel plow

Conventional tillage (91): a traditional system consisting usually of primary tillage followed by some secondary tillage operation for weed control or seedbed preparation

Cultivation: a tillage operation used in preparing land for seeding or transplanting or later for weed control and for loosening the soil

Erosion: the detachment and movement of soil by water, wind, or other geological agents

Field capacity: the percentage or volume of water remaining in a soil having been saturated and after free drainage has practically ceased. Normally associated with an equivalent negative pressure in the soil water of 1/3 atmosphere tension

Infiltration: the downward entry of water into the soil

[1]Unless otherwise noted, all definitions were taken from:
Canadian Society of Soil Science, Glossary of Soil Terms in Canada, 1967.

Minimum tillage (91): the minimum soil manipulation necessary for crop production or meeting tillage requirements under existing soil and climatic conditions. Minimum tillage does not define a system of tillage, but generally refers to a system with fewer tillage operations than some conventional tillage system.

Pans: horizons or layers, in soils, that are strongly compacted, indurated or very high in clay content

Pore space: total space not occupied by soil particles in a bulk volume of soil

Residue: usually organic material remaining on the soil surface from crop growth

Runoff, surface: that portion of precipitation which is lost without entering the soil

Soil moisture: water contained in the soil

Stubble mulching (66): a system of crop residue management using tillage, generally without any soil inversion, usually with blades or V-shaped sweeps

Summerfallow (91): a system of fallowing in which vegetative growth is restricted by shallow cultivation or a herbicide application during the summer months in order to conserve soil moisture. This usually infers the omission of a crop during the summer growing season in semiarid areas.

Wilting point: the percentage or volume of water remaining in the smallest pores and around the solid particles after the moisture removal by plant uptake. Normally associated with an equivalent negative pressure in the soil water of 15 atmosphere tension.

Zero tillage (91): a system whereby a crop is planted directly into a seedbed untilled since harvest of the previous crop

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