THE INFLUENCE OF TILLAGE AND ROW SPACINGS ON YIELDS AND SOIL WATER CONTENT IN A WHEAT GRAIN SORGHUM DOUBLE CROPPING SYSTEM

By

GIRMA ALEMU MAKONNEN

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National University

Alemaya, Ethiopia

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Thesis Approved:

R. Jewell Crabtree
Thesis Adviser

Robert L. Reisbeck

Billy B. Tucker

Charles E. Denman

Norma N. Durham
Dean of the Graduate College

1096412

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CHAPTER I

INTRODUCTION

The amount of arable land is relatively fixed. Thus, increased demands of agricultural products must be met by increasing yields per unit area of land. One way of achieving this goal is through a double cropping system.

Double cropping is growing two successive crops from the same field during one year. It encourages more efficient utilization of land, machinery, labor and capital investment. Favorable climatic conditions and soils that have the potential for double cropping enable farmers to maximize profit and net income.

Small grains, such as wheat (Triticum aestivum L.) followed by grain sorghum (Sorghum bicolor L.) make one of the best combinations of agronomic crops for a successful double cropping practice. Due to the competition for moisture by the preceding crop, and high atmospheric demand as well as dwindling rainfall during the summer growing season, it has in some cases been difficult to establish a good stand of the second crop using the usual farming practices. However, interest has been stimulated in double cropping by recent developments in minimum or no-tillage when preparing the seedbed, short-season crop varieties, narrow rows, no-till planting techniques and improved chemical weed control methods for the second crop.

The objectives of this study were (1) to identify the most desirable tillage methods and row spacings for a wheat followed by grain sorghum double cropping system, (2) to analyze the effects of tillage methods and row spacings on the volumetric soil water content in a wheat followed by grain sorghum double cropping system.

CHAPTER II

LITERATURE REVIEW

Tillage

Soil tillage is a basic agricultural operation characterized by complex objectives with a wide choice of methods and much diversity of opinion (1). Since man began to cultivate crops for food, various tillage practices have evolved, ranging from the primitive hoe to the current complex conventional, minimum and no-till systems (43, 7, 38).

According to Fenster (18) the primary purposes of tillage are to control weeds, control erosion and prepare a seedbed. Bauemer and Bakermans (2) reported that soils are tilled to provide conditions suitable for optimum plant growth and necessary field operations, such as planting and harvesting.

Larson (33) illustrated that when a layer of soil with a bulk density of 1.4 gm/cm^3 was loosened by plowing to a bulk density of 1.0 gm/cm^3, the total porosity was increased from 47 to 62% and the total amount of water that could be stored in the initial 18 cm of soil profile was also increased from 8 to 17 cm. Bauemer and Bakermans (2) reported on a study conducted by Ehlers (15) in Germany concerning the porosity and pore size distribution of an arable silt loam soil. They indicated that the total porosity in the top 2-6 cm layer was higher in the tilled soil than the untilled soil. This was accompanied by an increase in larger pores in the tilled soil, which was attributed to the mechanical loosening effects during plowing. However, the medium, small and very small pore size fractions showed virtually no difference. On the other hand, the space occupied by larger pores with uninterrupted connections to the atmosphere was more than double in the top 20 cm of no-tilled soil as compared to the plowed soil.

Blake (7) regarded tillage as a "necessary evil." However, he questioned if the soil clods should be finely broken up during a seedbed preparation since most seeds are placed at a depth between 1 and 5 cm. This means that only a few cm of loose, fairly pulverized soil is necessary to insure that the seed is covered and able to obtain moisture for germination. Larson (33) reiterated that neither pulverizing the soil to a depth of more than 6 cm was necessary to get the seed in the soil, nor more than a few cm horizontally around the seed, though traditionally a seedbed is made on the whole soil surface even when planting in rows 100 cm apart. Larson (34) has further challenged the past method of farming that involved tilling the entire soil surface in preparing the seedbed. He reported that the soil near the seed along the row zone, which is about 20% of the surface area, has large effects on plant growth from germination to harvest while the remaining 80% in the inter-row zone affects water intake. Thus, Larson concluded that they should be tilled differently. He suggested that the soil in the inter-row zone be tilled in such a way that it would be loosened and have a rough surface so that the large pore spaces that result would provide ready access to water from the surface and enable a given soil to absorb it quickly. Larson cautioned that too much tillage in the row zone produces small soil particles and small pore spaces making it difficult for water and air to circulate easily, slow for the soil to warm and often crusting when the soil dries. This effect could result in retarding germination, seedling emergence, early growth and root development (34).

As far as weed control is concerned, Blake (7) reported that all cultivation could be eliminated in some crops by leaving the soil loose, rough and cloddy between crop rows and spraying with a herbicide. He believed that weeds germinate and grow better on a pulverized smoothed seedbed than if the soil between rows of small seeds was rough. Blake concluded that since it would not be reasonable to germinate all weeds and then destroy them, tillage therefore should be aimed at preventing their germination. Wiese and Staniforth (57) reiterated that weed seeds possess special germination mechanisms related to tillage since soil disturbance may trigger the mechanisms through changes in soil moisture, temperature, oxygen supply, exposure to light, change in depth of burial and alternate wetting and drying at the sites of soil seed contact.

Conventional Tillage

Conventional tillage is a system of soil preparation for planting which includes plowing, disking, harrowing (33) and in many cases subsequent cultivating (51). Its effects involve not only changes in weed population, but also in the soil physical conditions which generally reduce the soil bulk density of the tilled layer by changing the size and arrangement of soil particles to improve water, air, temperature and mechanical relationships, promote biological activity (1, 34) and carbon dioxide production by soil microbes (32).

According to Baver et al. (4) the mechanical functions of the plow consist of the cutting loose, granulation and inversion of the furrows slice, and the turning under of residues and weeds. Page et al. (46) stated that plowing provides the opportunity to loosen the soil whose density has increased by the action of water and by contact with men and machines thereby increasing the porosity of the surface layer. Relchenberger (49) reported that plowing provides a uniform seedbed, improves seed soil contact and permits uniform depth of seed placement. Furthermore, plowing decreases severe weed problems by burying weed seeds too deep to germinate, provides a mellow surface to discourage grass weed seedlings (49) and also cuts the rooting system so that the weeds die from desiccation. Renegade weed species prosper under reduced tillage where a high reliance on chemical control often forces a shift in weed population. This shift in weed population forced wheat growers in Kansas and Nebraska to plow on a rotational basis to assure control of those weed species that are tolerant of herbicides (49).

As explained by Musick and Petty (43) surface trash, decaying organic matter from crop residues and grassy or weedy fields in no-tillage systems would provide an ideal situation for attracting and harboring female flies to oviposit and consequently for maggot infestation which eventually attack corn seeds. They also indicated that soil-inhabiting insects may be the most serious threat to no-till corn production, while conventional tillage not only exposes grubs to environmental stress, parasites and predators, but also enables insecticides to be incorporated into the soil. In the northern Corn Belt, deep-plowed soils dry and warm quicker in the spring, thus promoting faster germination and better early stand establishment (49). No-tillage, on the other hand, lowers soil temperature thereby prolonging seed germination and subsequent seedling growth (43).

According to Fenster (17, 18), disking gives a cutting and turning action of the soil, providing good control of weeds, burying 30 to 70% of the residue and, to a certain degree, pulverizing the soil.

Harrowing, along with disking, leaves smooth soil surfaces in a conventionally prepared seedbed (33).

Rapid infiltration of rainfall, adequate aeration and the breaking of surface crusts are the most significant reasons for cultivating crops (4). Field cultivators are effective for controlling small weeds, roughening land and bringing clods to the surface (18). Meggett (39) reported that on heavy soils or soils with poor tilling qualities, one or two cultivations increased corn yields even where herbicides had provided complete weed control.

Minimum Tillage

Larson (33) defined minimum tillage as a group of soil preparations for planting in which the number of operations and trips over the field is less than in conventional tillage. It includes wheel-track and plow-plant methods. Blake (7) explained that tillage in it's broadest sense includes all traffic on the soil required to grow the crop. It comprises of such trips over the soil to prepare a seedbed, apply fertilizer, plant and care for the crop, control weeds, insects and diseases; harvest the crop and dispose of the residue. However, since such trips during a growing season are usually destructive of the porosity created by plowing, the concept of minimum tillage perceived by Blake (7) involves omitting unnecessary tillage and combining a number of tillage practices in the same trip. From the use of such tillage systems, the time and cost of tillage weed competition, water runoff and erosion would be reduced.

Arndt and Rose (1) indicated that mechanization may have encouraged excessive traffic necessitating excessive tillage and resulting in soil compaction. Voorhees (56) reported that the total amount of wheel traffic put on a field during one growing season could be extensive. He illustrated that a six-row operation covering a width of 4.5 m and using 45 cm wide rear tractor tires would make enough wheel tracks to cover every 6.45 cm^2 of field about twice. Baeumer and Bakermans (2) reported that changes in total pore space and pore size distribution with depth showed that the layers at 0 to 15 cm and 25 to 30 cm depths were compacted compared to the layer at 15 to 20 cm depth. They attributed the compaction, at the 25 to 30 cm depth to the pressure and smearing action during plowing which resulted in a reduction of large pores and a relative increase in small and very small pores. A decrease in large, mostly air filled pores would induce a reduction in aeration. Baver et al. (4) reported that compaction destroys larger pores, partially filling them with solid particles thereby decreasing infiltration and optimum moisture content. They observed as much as 62% reduction in aeration porosity in the upper 15 cm of surface soil resulting in a decrease of 74% water intake. Soomers (53) also reported that compaction reduced pore space, thereby curtailing root development since some roots have trouble entering soil pores smaller than their tip diameters.

Larson (33) explained that minimum tillage systems leave soils with uneven microrelief which often maintain a higher water intake rate than smooth surfaces prepared by conventional tillage systems. He reiterated that during an intense rain a soil surface with uneven microrelief can store more water for later intake into the soil which is especially desirable on permeable soils where erosion control and moisture conservation are the major problems.

According to Lepper (35) disk-plant and chisel-disk systems cut soil loss due to water erosion 62 and 43%, respectively, compared to moldboard plow tillage in an Illinois trial. Larson (33) also reiterated that reduced tillage systems for row crops following sods tend to leave the particles at the soil surface bound together by the dead roots, while conventionally prepared seedbeds destroy much of this binding through disking and harrowing, making it susceptible to erosion hazards by wind and water.

According to Nelson et al. (45) the mulches and rough surfaces that result from minimum tillage conserve water by increasing infiltration and, hence, the amount of water available for subsequent crop growth. In the Pacific

Northwest, Lewis (36) reported that some tillage was needed to retard capillary water movement to evaporating sites near the soil surface. Effective erosion control, a decrease in evaporation and greater ability of the soil to store moisture in reduced tillage systems resulted in a water reserve which carried the crop through periods of short-term droughts and avoided the development of detrimental moisture stress in the plants under varied crop, soil and climatic conditions (8, 29, 45).

Research with conservation tillage practices has shown that runoff erosion and evaporation losses from the soil surface can be reduced (45). A concerted concern for less pollution of lakes, streams and reservoirs from soil erosion and runoff has prompted researchers to develop and continue to evaluate systems that require less tillage (51). Reduced tillage should continue to expand on marginal land where erosion is a problem (49). Sanford et al. (51) concluded that when unsatisfactory results were obtained in Mississippi from reduced tillage methods, they were usually related to poor weed control, poor management or lack of knowledge of the complete technology of crop production.

No-Tillage

Baeumer and Bakermans (2) define no-till as a tillage system in which mechanical soil manipulation is reduced only to traffic and seedbed preparation. Sanford et al. (51) also define no-tillage as a term which refers to tillage only by the coulter at planting in the seed zone, usually 5 cm wide and 10 cm deep. As far as the planting operation is concerned, Hinkle (28) reported that the primary function of a no-till planter is to open a narrow slit for seed placement followed by some method to press the soil around the seed.

Although deep-tillage operations by powerful tractors have been considered by some to be the more advanced system of crop production, interest in recent years has been stimulated in no-tillage systems due to the development of herbicides and planter modifications (2, 51). Bauemer and Bakermans (2) reported that Garber had successfully established a legume in an unproductive sod without tillage as early as 1927. Garber used such simple techniques as close grazing or burning to control unwanted vegetation, heavy seeding rates to overcome the competition by weeds and the hooves of grazing animals to bring the seeds into close contact with the soil.

Some advantages of no-till systems include conservation of moisture, preservation of added fertilizer, less requirements for energy, labor and machinery; increased land utilization by multiple cropping, therefore maximizing production per unit area of land and increasing flexibility in timing of farm operations (2, 3, 37, 45, 50). No-tillage also enables plant residues to remain on the soil surface and is essential where soil erosion by both wind and water limit successful farming.

Tillage and traffic by heavy implements on medium to fine textured soils during a wet season can result in the formation of soil pans, whereas the continued use of no-tillage would result in a more stable soil structure that would provide more optimum conditions for plant growth. Where a crumbly and friable structure has been established, slaking of silt material and consequently formation of a dense crust are rarely observed on no-tilled silty loam soils (2). Blevins et al. (8) pointed out that regions with large acreage of sloping land, adequate rainfall, and medium textured surface soils are particularly suited to no-tillage because of the existing high erosion hazard under conventional tillage.

According to Hinkle (28) the common method used in Arkansas in double cropping systems is to burn the wheat straw, disk twice, harrow and then plant soybeans, provided sufficient moisture was available. However, those operations resulted in loss of soil moisture which either delayed planting while waiting for rain, or if planted, resulted in a poor or uneven stand of soybeans. No-till method was, therefore, an alternative method of double cropping after small grain. Gallaher et al. (21) also made a similar report in double cropping wheat and forage sorghum. They have shown that planting time was critical if the normal maturity date of the preceding crop extended beyond the normal planting date of the second crop. No-till planting, therefore, provided the least delay permitting immediate planting after the small grain harvest. Gallaher and his associates also reported that no-till planting conserved scarce soil moisture resulting in quick germination, fast growth and increased the chances for success in double cropping.

Hill and Blevins (27) studied the quantitative soil moisture use in Kentucky on a silt loam soil and found that no-tillage resulted in an increase in the yield of corn by making water more readily available to the plants. This was accomplished primarily by reducing water losses early in the growing period when direct evaporation from the soil surface was at a maximum. The higher moisture contents at any one time in the no-till plots resulted in a greater unsaturated conductivity of the soil, and thus, with water more freely available, the plants were not under as much stress as those in the conventional tilled treatments. As a result, the yield for the no-till treatment showed an additional average increase of 6.25 q/ha over that of conventional tillage.

Moschler et al. (40) compared continuous no-till corn with surface applied lime to continuous conventionally tilled corn with lime incorporated into the silt loam soil over an eight year period in Virginia. The additional yield increase (31.3 vs 13.5%) on no-till was attributed to higher calcium at the surface, which contributed to increased organic matter and soil moisture. They also observed a three fold increase in water use efficiency, a ten fold increase in total corn root length, a decrease in the toxic aluminum at the 0 to 5 cm surface layer in the no-till as compared to the conventionally tilled corn. Moschler et al. (42) also compared yield and fertilizer efficiency on three soil types using corn as a test crop in Virginia. They concluded that higher yield coupled with some increases in residual nutrients would indicate not only a more efficient fertilizer use but also the differences in productivity were related primarily to a greater infiltration of water and waterholding capacity under the no-till culture, as compared to the conventionally tilled treatments.

Bennett et al. (5) compared corn production in West Virginia, on a silty clay loam soil with steep terrain using no-till and conventional tillage methods. They reported that lower soil temperatures under the mulch in the no-till treatments reduced evapotransporation and runoff rates and resulted in a significantly higher amount of available soil moisture for plant growth. Lewis (37) attributed higher yields of corn in a no-till system to greater moisture reserves which were not depleted by the seedbed preparation as in the conventional tilled system.

Bennett (6) reported that surface residues in a no-till system increased infiltration, reduced evaporation and lowered the soil temperature, which resulted in significantly more water for plant growth throughout the growing season. In addition, plants were better able to use moisture from small rains because roots grew near the soil surface under the mulch in the no-till system (6, 17). As explained by Hayes (26) the greatest differences in yields for mulch tilled corn on well drained soils occurred usually in dry years. On heavy soils, however, mulch tillage often resulted in lower corn yields.

Moschlers et al. (41) observed much more earthworm activity and soil mixing creating more channels for water penetration under a no-till corn culture as compared to conventional tilled plots on a silt loam soil in Virginia. Baeumer and Bakermans (2) also observed an average of 68 vs 15 tunnels on a no-tilled and plowed stubble cropping system, respectively. They indicated that earthworm channels which open to the soil surface may influence the rate of water infiltration.

Ehlers (16) reported that on conventionally tilled Grey Brown Podzolic soils derived from loess, rapid water infiltration was delayed by a surface seal of silt and a dense traffic layer. On the other hand, the no-till system induced a reduction of porosity, but an increase in aggregate stability in the top layer. As a result, clay-silt segregation was not observed and traffic pans were loosened by biological activity enhancing water infiltration against existing hydraulic gradients. Baeumer and Bakermans (2) indicated that differences in soil water content between tilled and untilled soils were small and inconsistent compared to differences in soil water tension. They reported that no-tilled soil with a similar water content had a lower soil water tension, which resulted in a smaller resistance to water uptake by plant roots and a higher conductivity of soil water.

Hill and Blevins (27) reported that fertilizer application, weed suppression and insect control in no-till systems require methods different from those of conventionally tilled corn production systems. However, they pointed out that with proper management, a no-till system in Kentucky resulted in greater net profits than conventional tillage systems. Gallaher et al. (21) indicated that since no major land preparation is necessary to produce crops in no-till systems, it requires fewer inputs than conventional tillage systems, thereby saving fuel, machinery and labor costs. They also reported that no-till systems enables farmers to harvest two crops per year from the same soil, in which the yields of each crop from double cropping were greater than or equal to those from monocropping resulting in increasing profit and more effective utilization of natural resources.

Row Spacing

According to Smith and Walker (52), planting crops close together is one of the simplest and oldest techniques for increasing production per unit area of land. This was accounted for by the fact that when crop rows touch, weed growth would be inhibited due to a lack of sunlight below the crop canopy and also results in less evaporation of water from the soil surface.

Porter et al. (48) also reported that grain sorghum grown in 30 or 50 cm rows in Texas produced not only higher grain and forage yields, but also higher water use efficiency than the 75 and 100 cm rows. They attributed these increases to a more uniform spacing of plants which resulted in more efficient use of moisture, nutrients and solar energy.

In many instances grain yield of sorghum would not be drastically affected by a wide range of plant densities due to its ability to compensate through grain yield components for changes in available space (9). Studies conducted in Israel by Blum (9) using three grain sorghum hybrids indicated that the highest yield was obtained with an early maturing hybrid planted at relatively high plant densities, while the late maturing hybrid performed best at lower plant densities. He also showed that under a limited moisture regime, early flowering varieties were more adapted to narrow row spacings and late flowering varieties were more adapted to wider row spacings.

According to Brown and Schrader (11) high plant populations and wide row spacings resulted in increased plant competition within the row. Their results showed reduced forage production, but increased grain production and water use efficiency. They attributed the increase in grain yield to the fact that with wide spaced rows, the soil moisture supply between rows was not exhausted as rapidly as in narrow rows, and was available later in the season when grain filling was taking place. They suggested that in extremely dry years, wide row spacing and low plant populations are desirable, regardless of the amount of stored soil moisture, while closer spacings and higher populations are recommended as seasonal rainfall increases.

Solar radiation absorbed by foliage is a primary input for crop growth and yield formation because it, to a large extent, determines the rates of photosynthesis, transpiration and sensible heat transfer (19). The light transmission in field communities of grain sorghum were studied in Nebraska by Clegg et al. (14). They reported that the amount of photosynthetically active radiation (PAR) transmitted through the canopies decreased as row spacing decreased from 102, 76 and 51 cm. Solar radiation was, therefore, intercepted more efficiently with narrow row spacings resulting in a favorable yield increase.

Chin Choy and Kanemasu (12) studied the effect of row spacing on the energy balance of grain sorghum in Kansas. Measurements were made on wide (92 cm) and narrow (46 cm) spaced rows with the same plant density of 12 plants per meter. Seasonal evapotransporation (ET) was about 10%

more from wide rows than from narrow rows of sorghum canopy. They attributed this increase in ET to the sensible heat component of the wide row plants which increased the transpiration over that of the narrow rows. Their study, therefore, suggested that sensible heat and, consequently, ET can be reduced by narrow spacing in grain sorghum.

Soil Water Management

Studies conducted in Texas showed that as little as 15 to 20% of the precipitation was stored as soil water (30). According to Blevins, et al. (8) soil moisture is normally lost from the plant root zone by evaporation from the soil surface, runoff as surface water, transpiration by growing plants and percolations to depths beyond the normal root zone. In the Great Plains, the soil-water reservoir is primarily depleted by evapotranspiration (24). As far as the soil-plant-air continuum is concerned, the amount of soil water used depends upon the atmospheric demand for water, the plant's ability to regulate the flow of water through the plant system, exploitation of the soil water reservoir by the root systems and the conductivity of the soil (55).

Practices, therefore, used to increase the precipitation efficiency include tillage, surface residues, chemicals (20, 23, 36), crop selection (sorghum), land leveling (30), partial soil surface covers of plastic film, asphalt film, asphalt coated paper (24), soil and gravel mulch (25).

Crop Selection

According to Brown and Schrader (11), grain sorghum is grown in areas where rainfall is normally deficient and limits other kinds of crop production. In many of the grain sorghum growing areas, no precipitation occurs during the growing season, and water is provided under dryland conditions by stored soil moisture (10).

It has been shown by Griffin et al. (24) that the small rains received during the summer growing season of grain sorghum on a silty clay loam soil in Oklahoma did not contribute materially to the available soil moisture supply. Blum (9) reported that grain sorghum can be grown in Israel on stored soil moisture without receiving any additional rainfall during the summer. Increases in grain production and water use efficiency were obtained in Texas through crop selection of grain sorghum because it converted precipitation to grain much more efficiently than wheat (30).

It has been shown by Teare et al. (55) that grain sorghum has the ability to remain quiescent when confronted with unfavorable conditions, although yields were markedly influenced at flowering if the grain sorghum remained under severe water stress. Lewis et al. (36) studied the susceptibility of grain sorghum to water deficit at three growth stages in Texas. Their results indicated that the yields were reduced by 17, 34 and 10% during the late vegetative to boot stage, boot through bloom stage and milk through soft dough stage, respectively, when the soil-water potential was dropped to -12.9 bars while being maintained above -0.7 bars during the remainder of the growing season.

Nakayama, et al. (44) studied the root activity of sorghum using P^{32} uptake and soil water depletion data on a Laveen loam soil in Arizona. They indicated that 90% of the sorghum root growth activity, at the rate of 1.9 to 5.1 cm of growth per day, occurred in the region 90 cm deep and 37.5 cm laterally from the plant, and 80 to 90% of the water was depleted from the surface 90 cm of a 150 cm soil profile.

Blum (10) indicated that sorghum roots grown in Israel under dryland conditions were able to explore and utilize stored soil moisture over a spacing of 240 cm between row pairs. Teare et al. (55) studied the water use efficiency and its relation to crop canopy, stomatal regulation and root distribution using grain sorghum and soybean as test crops on a silt loam soil in Kansas. They concluded that grain sorghum with its fibrous root system had twice the roots by weight per unit volume of soil compared to soybeans which gave it a greater absorbing surface area than soybeans. The grain sorghum had a smaller transpiring area and better ability to close its stomata before soybeans which enabled it to withstand greater drought stress.

Chin Choy and Kanemasu (12) studied an evapotranspiration (ET) model for soybean and sorghum in Kansas. They reported that the leaf area index (LAI) for sorghum was less than soybean, which resulted in 13% greater ET from the soybean canopy than from grain sorghum because the latter had greater surface resistance. Grain sorghums, therefore, as a group, are among the most drought resistant field crops (55).

Mulches

In the Great Plains, straw (wheat) is the primary mulching material used to assist in wind erosion, improve soil water storage during fallow and improve organic matter conditions resulting in increased nitrogen mineralization and availability of phosphorus (22).

Studies conducted by Greb et al. (23) at three widely separated Great Plains locations in Colorado, Nebraska and Montana demonstrated that increasing the amounts of straw mulch consistently increased storage of soil water in fallow soils during 16 years of testing. The mean net gain in soil water from mulch production of 26.9, 40.3 and 61.6 q/ha increased by 2.5, 3.0 and 5.0 cm, respectively, per fallow season. Greb et al. (23) also reported that more soil water was stored where there had been standing stubbles because the stubble trapped and deposited blowing snow better than surface residues. They also indicated that mulches conserved extra water during frequent rainy periods, but had little effect during long dry seasons.

Koshi and Fryrear (31) conducted a study in Texas on Acuff loam soil using cotton bur as a surface mulch at rates greater than 11.2 tons/ha. The cotton bur increased the saturated hydraulic conductivity, organic matter, air and total porosity, and decreased the bulk density of the surface 15 cm of soil profile which resulted in improved soil-water-plant relationships. According to Blevins et al. (8), mulch sod significantly reduced evaporation during the early period of the growing season in corn culture in Kentucky on a silt loam soil. High moisture levels were observed near the mulch-soil interface following shower activity. They attributed this zone to be high in organic residue which has greater capacity to store water owing mainly to its high absorptive properties.

As explained by Griffin et al. (24), increased moisture efficiency and good crop yields were obtained by eliminating or controlling soil surface evaporation in Oklahoma on a silty clay loam soil through such techniques as partial soil surface covers of plastic film, asphalt film and asphalt coated paper. Maximum results were obtained from plots with 100% surface cover and was indicative of the moisture conserving potential of eliminating soil surface evaporation. According to Smith and Walker (52), black polyethylene sheeting was more effective than organic mulches as far as minimizing evaporation was concerned.

They also reported that such a cover helped to inhibit weed growth and to warm seedbeds in the spring.

Studies conducted in Kansas by Hanks and Woodruff (25) showed that soil was a more effective mulch in reducing evaporation than gravel or straw. Increased depths of soil mulches decreased evaporation rates with most of the decrease occurring by increasing the mulch depth from 0 to 0.6 cm. Extensive studies were made by Papendick et al. (47) in Washington on a silt loam or fine sandy loam soil to determine the effect of soil mulches on seedbed temperature and water relationship during fallow season. They reported that the water-conserving effect of a soil mulch was related to the lowered temperature and temperature gradients across the seed zone with an increased mulch depth. They explained that the loose, dry mulch at the surface caused thermal insulation of the moist soil below. As a result, the heat flow downward was reduced because the soil thermal conductivity would be decreased. The dry layer across which evaporation loss occurs as a vapor flow reduced water loss and conserved seedbed water by lowering the rate of energy exchange between the atmosphere and the underlying moist soil, and by increasing the resistance to liquid water flow to the soil surface. Papendick and his associates also attributed the benefits of soil mulches for their water conserving properties to reducing evaporation through disrupting capillary flow to the evaporation sites.

Antitranspirants and Reflectants

Excessive radiant heat load limits the growth of plants in dryland farming during the rainless summer (19). It has been shown by Fuehring (20) in New Mexico that phenylmecuric acetate (PMA), atrazine, and Folicote antitranspirants applied prior to the boot stage on grain sorghum decreased water loss from plant leaves by not only reducing the size or number of stomatal openings, but also decreasing the rate of diffusion of moisture vapor without restricting photosynthesis. The antitranspirants reduced the degree and length of periods of moisture stress and increased the amount of time when photosynthesis took place resulting in increasing yields 8 to 17%.

Studies conducted in Israel on a dark brown clay soil by Stanill et al. (54) showed that kaolin suspensions sprayed twice on the foliage of grain sorghum during the pre-panicle emergence stage resulted in an additional yield increase of 4.5 q/ha or 11% over the unsprayed control during the three years of experimentation. They attributed the yield increase to kaolin increasing the foliage reflectivity and decreasing its radiation heat load. Such effect caused an increase in transpiration resistance to the potential water demand of the atmosphere, thereby improving the internal water status of the treated plants. Soil-only applications of kaolin, however, were ineffective in increasing the grain yield.

CHAPTER III

MATERIALS AND METHODS

Field studies were conducted on double cropping wheat followed by grain sorghum at the Oklahoma Vegetable Research Station located near Bixby, Oklahoma. This double cropping experiment was established on a Wynona silty clay loam soil with 0 to 1% slope. The soil is presently classified as a fine, silty, mixed, thermic, Cumulic, Haplaquolls. The research was a two year study which started in December, 1975 and was completed in November, 1977.

Winter wheat (*Triticum aestivum* L.) of variety Tam W-101 was planted on December 11, 1975 and November 22, 1976 at a rate of 100 kg/ha. A John Deere hoe drill was used to plant the wheat with row spacings of 25 cm. The seedbed for wheat was prepared by moldboard plowing and two tandem diskings. Each plot was 6.1 m wide and 53.3 m long. The wheat was topdressed by broadcasting 45 kg/ha nitrogen (N) as ammonium nitrate (NH_4NO_3) and 112 kg/ha of dipotassium oxide (K_2O) as murate of potash (KCl) on February 20, 1976; and with 50 kg/ha as NH_4NO_3 on March 16, 1977. Wheat grain yields were harvested on July 7, 1976 and June 16, 1977 by combining 3.05 m from the center of each plot so as to avoid any border effect.

After the wheat was harvested, grain sorghum (Sorghum bicolor L.) hybrids, Northrup King 233A and Acco BR-Y93, were planted on July 10, 1976, and June 18, 1977, respectively. An Allis Chalmers no-till planter equipped with 5 cm fluted coulters, double-disk openers and 4 cm depth bands was used to plant the grain sorghum at a rate of 9 kg/ha. Prior to planting the grain sorghum, 135 kg/ha N as NH_4NO_3 on July 9, 1976 and 135 kg/ha N as urea on June 17, 1977 was broadcasted on all the grain sorghum treatments. The contact herbicide, Paraquat [(1,1'-dimethyl-4, 4'bipyridium ion (as dichloride salts)] and Linuron [(3-(3,4-dichlorophenyl)-1-methylurea)] for control of germinating broadleaf weeds and grasses, with 0.5% by volume surfactant was broadcast-sprayed preemergence at a rate of 1.12 and 0.56 kg/ha, respectively, in 235 l/ha of water just after planting. Lannat, S-methyl-N-[(methylcarbamoyl) oxy] thioacetimidate was used to control insects, which were predominantly corn earworms, at a rate of 2.3 l/ha. Harvesting of the grain sorghum was done by combining a 3.05 m strip from the center of each plot on September 24, 1976 and November 12, 1977.

The 4 x 2 factorial experiment consisted of 4 tillage management systems (conventional tillage (CT), minimum tillage (MT), no-tillage (NT) and single crop (SCG) conventional tillage) and two row spacings (50 and 75 cm), giving eight treatment combinations for grain sorghum plus a single crop conventional wheat (SCW). The experimental plot layout was a randomized complete-block design with four replications.

Conventional tillage plots were moldboard plowed and tandem disked twice; minimum tillage plots were only tandem disked twice; no-tillage plots were seeded directly into the standing stubble; and the single crop plots were moldboard plowed and tandem disked twice as in the conventional tillage plots.

Water content of the soil profile was monitored during the growing season. Readings were taken in accordance with the different physiological stages of growth for the two crops. These growth stages include when the wheat was watery ripe and fully ripe; and for the grain sorghum when the collar of the fifth leaf was visible, boot and hard dough physiological stages of growth.

A Nuclear-Chicago P-19 probe was used to measure the soil-water content (% by volume). Readings were made at depths of 15, 30, 45, 60, 75, 90, 105 and 120 cm. There was one neutron probe access tube in the center of each plot, with the exception of the minimum tilled plots, in three out of the four replications. The 15-cm reading utilized a calibration curve which was developed for this depth. All other depths were from a curve developed for deep readings (13).

CHAPTER IV

RESULTS AND DISCUSSION

1976 Grain Sorghum Yields

For the purpose of discussion, tillage treatments will be referred to as conventional tillage, 50 cm rows (CT-50); conventional tillage, 75 cm rows (CT-75); minimum tillage, 50 cm rows (MT-50); minimum tillage, 75 cm rows (MT-75); no-tillage, 50 cm rows (NT-50); no-tillage, 75 cm rows (NT-75); single crop conventional grain sorghum, 50 cm rows (SCG-50); and single crop conventional grain sorghum, 75 cm rows (SCG-75).

The 1976 growing season was unusually dry. The annual precipitation was more than 30% below the 25-year average (Table I). The precipitation received during the grain sorghum growing period, from July to October, was also more than 20% below normal (Table I).

The analysis of variance for all 1976 grain sorghum yields indicated that row spacing and the interaction of tillage management times row spacing had significant effect upon grain yields between treatments (Table II). Variation among replications was significant, indicating the heterogenous nature of growing conditions for the same location.

TABLE I

DISTRIBUTION OF RAINFALL (mm) FOR 1976 AND 1977 COMPARED WITH THE 25-YEAR AVERAGE (1950-1975) AT VEGETABLE RESEARCH STATION, BIXBY OKLAHOMA

Month	25-Year Average (1950-1975)	1976	1977
January	39.1	0.0	21.6
February	41.4	17.8	40.1
March	66.0	71.9	87.4
April	99.6	141.2	52.6
May	118.4	62.0	127.5
June	115.6	42.7	94.7
July	94.0	69.3	84.3
August	71.1	85.1	76.5
September	111.0	79.8	217.4
October	81.5	49.8	50.8
November	65.5	16.3	68.3
December	48.3	27.9	17.8
Totals	950.5	663.7	939.0

TABLE II

ANALYSIS OF VARIANCE FOR ALL 1976 AND 1977 GRAIN SORGHUM YIELDS (q/ha)

Source	df	Mean Squares	
		1976	1977
Total	31	2860	4009
Replication	3	5119*	2027
Tillage Management (TM)	3	2331	8815
Row Spacing (RS)	1	9866*	2625
TM x RS	3	7758**	4619
Error	21	1579	3584

*, **Significant at the 0.05 and 0.01 probability levels, respectively.

The combined average grain yields under all the four tillage management systems, including the single crop grain sorghum, were compared regardless of the row spacing effect. The data indicated that 40.14 q/ha for CT, 39.69 q/ha for MT, 36.62 q/ha for NT and 37.45 q/ha for SCG were obtained (Table III). These were not significantly different. The 1976 results, therefore, suggest that double cropping grain sorghum after wheat harvest using the above mentioned tillage treatments would result in similar yields as mono-cropped, conventionally tilled grain sorghum when all are planted at the same date.

Significantly higher average grain yield resulted from the use of 50 cm rows than 75 cm row spacing. The higher yield, 40.23 vs 36.72 q/ha, obtained from narrow rows may, in part, be attributed to a quicker canopy cover decreasing weed competition and loss of water by surface evaporation early and throughout the growing season.

TABLE III

MEAN VALUES FOR GRAIN SORGHUM YIELDS (q/ha)

Tillage Management	1976 Row Spacing (cm) 50	75	Mean	1977 Row Spacing (cm) 50	75	Mean
CT	39.88	40.41	40.14	38.46	30.56	34.51
MT	45.78	33.60	39.69	40.76	44.33	42.54
NT	35.89	37.35	36.62	39.59	39.36	39.48
SCG	39.37	35.52	37.45	40.64	37.96	39.30
$LSD_{.05}$	5.85	5.85	N.S.	N.S.	N.S.	N.S.
Average	40.23	36.72	38.48	39.86	38.05	38.96
$LSD_{.05}$	2.92	2.92	--	N.S.	N.S.	--

The overall mean of grain sorghum yield was 38.48 q/ha. The highest average yield was 45.78 q/ha obtained under

MT-50. The cause for highest grain yield for MT-50 may, in part, be due to the row spacing effect and the interaction of tillage and row spacing (Tables II and III).

1976 Grain Sorghum Yields from Treatments Where Water Was Monitored

Water was monitored in CT-50, CT-75, NT-50, NT-75, SCG-50 and SCG-75 treatments. Analysis of variance was run involving grain yields from these plots for the three tillage management systems and two row spacings. The results showed no significant differences between treatments due to tillage or row spacings (Table IV).

TABLE IV

ANALYSIS OF VARIANCE FOR 1976 AND 1977 GRAIN SORGHUM YIELDS WHERE WATER WAS MONITORED

Source	df	Mean Squares 1976	Mean Squares 1977
Total	17	1604	3986
Replication	2	3896	3551
Tillage Management (TM)	2	1717	2290
Row Spacing (RS)	1	2651	18102*
TM x RS	2	1134	1761
Error	10	1112	3445

*Significant at the 0.05 level of probability.

The average yields obtained from double cropped CT and SCG were similar, but greater than double cropped NT. The cause for a reduction in yield in the latter may have been due to infestation of weeds, mainly Johnson grass encountered under NT throughout the growing period. Conversely, the moldboard plowing and two tandem diskings in both CT and SCG may have contributed to a better weed control, especially early in the growing season. However, the yields due to tillage involving double cropping or monocropping were not different at the 0.05 level of probability (Tables IV and V).

TABLE V

MEAN VALUES FOR GRAIN SORGHUM YIELDS (q/ha) FROM TREATMENTS WHERE WATER WAS MONITORED

	1976			1977		
Tillage	Row Spacing (cm)			Row Spacing (cm)		
Management	50	75	Mean	50	75	Mean
CT	39.98	38.58	39.28	40.84	30.59	35.72
NT	36.14	35.80	35.97	40.60	35.65	38.13
SCG	41.02	35.48	38.25	41.50	37.67	39.58
$LSD_{.05}$	6.07	6.07	N.S.	10.68	10.68	N.S.
Average	39.05	36.62	37.83	40.98	34.64	37.81
$LSD_{.05}$	N.S.	N.S.	--	6.17	6.17	--

As far as row spacing was concerned, yields of grain sorghum were higher (39.05 vs 36.62 q/ha) using 50 cm rows than 75 cm row spacing. However, the statistical analysis did not show any difference at the 0.05 level of probability (Table V).

1977 Grain Sorghum Yields

The 1977 growing season was a better year than the preceding one as far as total annual rainfall was concerned. The precipitation received from July to October was 20% more than normal. Nonetheless, the distribution was highly erratic since more than 50% of the precipitation during this same grain sorghum growing season occurred only in September. The September precipitation was 95% more than the 25-year average (Table I). Although such a higher rainfall in September may have been helpful during the grain filling period, the grain sorghum plants were under stress from lack of moisture in the early growing season. In addition, they were confronted by a series of severe heat waves that crossed all over the state during the same period.

Analysis of variance for all the 1977 grain sorghum yields indicated that there were no differences due to the tillage management systems and row spacings or the interaction of the two levels (Table II).

The yields of grain sorghum were averaged over all the four tillage management systems, including the single crop treatments. Higher yields were obtained from double cropped MT and NT plots than the SCG (42.54 and 39.48 vs 39.30 q/ha, respectively). A lower yield of 34.51 q/ha was obtained from double cropped CT treatment. However, they all were not different at the 0.05 level of probability (Table III). The results, therefore, again suggest similar yields of grain sorghum could be obtained in a double cropping system as compared to a single crop grain sorghum system if both cropping systems were planted at the same date.

The overall mean of grain sorghum yields during the 1977 harvest was 38.96 q/ha. These results were very similar to the preceding year (Table III).

1977 Grain Sorghum Yields from Treatments Where Water Was Monitored

The analysis of variance data showed that grain yields due to row spacing effect were significantly different at the 0.05 level of probability. However, tillage management or tillage management x row spacing did not influence the 1977 grain sorghum yields between treatments (Table IV).

Yields were averaged over the different tillage methods to detect significance between 50 and 75 cm row spacings. A total of 40.98 vs 34.64 q/ha was obtained from the use of narrow rows (50 cm) as compared with the wider rows (75 cm). This was significant at the 0.05 level of probability (Table V). Higher yields under narrow rows suggest a better suppression of weeds, reduction of surface evaporation and probably improved water use efficiency compared with wider rows.

1977 Wheat Yields

The wheat growing season in eastern Oklahoma extends approximately from November to June. The precipitation received during this period for the 1977 wheat crop at Bixby was more than 21% below the 25-year average. In addition, the total rainfall from March to June made only 90% of the normal distribution (Table I).

The analysis of variance for the 1977 wheat yields show a significant difference between treatments (Table VI). This was brought about by a much larger yield obtained from the single crop treatment. The yields from double cropped treatments ranged from 59 to 68% of the single crop wheat plots (Table VII). The cause for such a wide variation in yields may be attributed to a heavy moisture removal by the double cropped grain sorghum, as well as low precipitation received during the growing season.

Another analysis of variance was run to detect the residual effect of tillage management systems and row spacings on the 1977 wheat yields. Yield differences due to row spacing was highly significant (Table VIII). The

TABLE VI

ANALYSIS OF VARIANCE FOR 1977 WHEAT YIELDS (q/ha), INCLUDING SINGLE CROP TREATMENT

Source	df	Mean Squares
Replication	3	937*
Treatment	6	3348**
Error	18	224

*, **Significant at the 0.05 and 0.01 probability levels, respectively.

TABLE VII

MEAN VALUES FOR 1977 WHEAT YIELDS (q/ha), INCLUDING SINGLE CROP TREATMENT

Tillage Management	Row Spacing (cm) 50	75	Mean
CT	22.17	19.29	20.73
MT	22.27	20.79	21.53
NT	21.73	19.25	20.49
	25	25	
SCW	32.55	32.55	32.55
$LSD_{.05}$	2.23	2.23	--

wheat yields were averaged over the double cropped tillage methods. Significantly higher yields were obtained from those plots that had grain sorghum with narrow rows during the summer growing season (Table IX). When wheat yields were averaged over row spacing practices of the previous crop, however, there were no differences in values at the 0.05 level of probability (Table IX). The results, therefore, suggest that tillage management methods used to establish the double cropped grain sorghum have no influence on yield differences among CT, MT and NT treatments of the subsequent wheat crop.

TABLE VIII

ANALYSIS OF VARIANCE FOR 1977 WHEAT YIELDS (q/ha), EXCLUDING SINGLE CROP TREATMENT

Source	df	Mean Squares
Replication	3	771*
Tillage Management (TM)	2	236
Row Spacing (RS)	1	3110**
TM x RS	2	104
Error	15	149

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

TABLE IX

MEAN VALUES OF WHEAT YIELDS (q/ha) FOR 1977, EXCLUDING SINGLE CROP WHEAT TREATMENT

Tillage Management	Row Spacing (cm) 50	75	Mean
CT	22.17	19.29	20.73
MT	22.27	20.79	21.53
NT	21.73	19.25	20.49
$LSD_{.05}$	1.84	1.84	N.S.
Average	22.05	19.78	20.92
$LSD_{.05}$	1.06	1.06	--

1976 Soil Water Retention

The analysis of variance for each sampling date showed that differences in total soil water content between treatments were highly significant except on May 19 and July 29, 1976 (Table X). Tillage management systems were different on all sampling dates. Depth x tillage management were significant on all sampling dates, except July 29. Row spacings, however, did not show any significant differences in total soil water throughout the 1976 growing season (Table X).

On the May 19, 1976 sampling date, higher total water values were obtained at the 15 to 60 cm depths on SCG-50

TABLE X

MEAN SQUARES FROM ANALYSIS OF VARIANCE OF WATER RETENTION (cm) FOR 1976 SAMPLING DATES

Source	df	Sampling Dates				
		May 19	June 19	July 29	Aug. 25	Oct. 1
Replications (R)	2	1.2262	1.1618	0.0198	0.4101	0.0407
Treatments (T)	6	1.8851	2.8787**	1.4689	3.4605**	2.8023**
Tam vs Others†	1	0.0001	0.5873	0.3257	11.1451**	13.6422**
Others	5	2.2621	3.3370**	1.6976	1.9236*	0.6343
Tillage Mgmt. (TM)	2	5.4860*	8.3020**	3.1745*	3.7360**	1.3873*
Row Spacing (RS)	1	0.0854	0.0172	0.5347	1.5683	0.0342
TM x RS	2	0.1265	0.0320	0.8021	0.2889	0.1814
Error A (R x T)	12	0.8092	0.4922	0.6091	0.4832	0.2451
Depth (D)	7	3.7004**	5.4270**	4.9477**	20.0878**	9.0268**
T x D	42	0.4366**	0.1657	0.0919	0.2842**	0.1195
(Tam vs Others) x D	7	0.0702	0.1127	0.0191	1.1986**	0.4560**
Others x D	35	0.5099**	0.1762	0.1064	0.1013	0.0522
TM x D	14	1.2236**	0.3470*	0.2111	0.1495*	0.0420
RS x D	7	0.0302	0.1484	0.0204	0.1282	0.0604
TM x RS x D	14	0.0360	0.0194	0.0448	0.0396	0.0584
Error B	98	0.1052	0.1800	0.1524	0.0796	0.1045
Total	167					

*, **Significant at the 0.05 and 0.01 probability levels, respectively.

†Refers to SCW vs CT-50, CT-75, NT-50, NT-75, SCG-50 and SCG-75.

and SCG-75 compared with the other treatments (Table XI and Figure 1). This difference was brought about because the former had been fallow since November, while the other treatments had wheat crop that was already watery ripe. Beyond 75 to 120 cm depth, however, there was similar soil water content in all the treatments (Tables XI and XII, Figures 1 and 2).

The wheat crop was at the fully ripe stage when readings were taken on June 19, 1976. There was a significant difference on total soil water only from 15 to 90 cm depth between SCG-50 and SCG-75 vs other treatments (Tables XI and XII, Figures 1 and 2) for the same reason mentioned above.

The wheat was already harvested and the grain sorghum was on its fifth leaf visible physiological stage on July 29, 1976. No significance was observed in all the treatments and at all depths, probably due to low precipitation received earlier during the 1976 growing season (Tables XI and XII, Figures 1 and 2).

By August 25, the grain sorghum had reached boot stage of physiological growth. There was significantly higher soil water on SCW treatment at 15-45 cm depth, probably due to a relatively higher precipitation received in late July and a higher evapotranspiration loss on the double cropped plots (Tables XI and XII, Figures 1 and 2).

TABLE XI

INFLUENCE OF TILLAGE AND ROW SPACINGS ON TOTAL SOIL WATER (cm) AT 15, 30, 45 AND 60 cm DEPTHS (MAY 19 - OCT. 1, 1976)

Treat-ments	Sampling Dates									
	May 19	June 19	July 29	Aug 25	Oct 1	May 19	June 19	July 29	Aug 25	Oct 1
	15 cm Depth					45 cm Depth				
CT-50	3.66	4.33ab	3.71	1.42a	4.11	3.03	3.00ab	2.55	1.32ab	1.93b
CT-75	3.53	4.05a	4.47	1.51a	3.86	2.95	2.86a	2.79	1.45abc	1.88b
NT-50	3.03	4.09a	3.64	1.40a	3.83	2.56	2.55a	2.24	1.28ab	1.91b
NT-75	3.18	3.65a	3.53	1.34a	3.80	2.82	2.51a	2.35	1.16a	1.26a
SCG-50	5.58	5.25bc	4.20	1.70a	4.25	3.48	3.70bc	3.30	1.78bc	1.86b
SCG-75	5.47	4.96bc	3.73	1.84a	4.19	3.78	3.89bc	3.04	1.94bc	2.16b
SCW	3.72	3.84a	3.95	2.86b	4.14	3.04	2.78a	2.78	3.01d	2.93c
$LSD_{0.05}$	N.S.	0.77	N.S.	0.61	N.S.	N.S.	0.77	N.S.	0.61	0.58
	30 cm Depth					60 cm Depth				
CT-50	2.66	2.61ab	2.36	1.04a	2.71ab	3.58	3.26ab	3.02	2.04a	2.00ab
CT-75	2.44	2.38a	2.70	1.00a	2.50ab	3.55	3.28ab	3.37	2.76b	1.83ab
NT-50	2.28	2.40a	2.44	1.04a	2.69ab	3.24	2.86a	2.89	2.21a	1.80ab
NT-75	2.58	2.31a	2.68	0.91a	2.36a	3.47	3.19a	3.16	2.07a	1.56a
SCG-50	3.52	3.34b	2.82	1.26a	2.57ab	3.73	3.99bc	3.98	2.91bc	2.25b
SCG-75	3.54	3.31b	2.80	1.40a	2.85ab	4.03	4.31bc	3.83	3.45cd	2.09ab
SCW	2.81	2.45a	2.66	2.65b	3.07b	3.77	3.45ab	3.60	3.57cd	3.40c
$LSD_{0.05}$	N.S.	0.77	N.S.	0.61	0.58	N.S.	0.77	N.S.	0.61	0.58

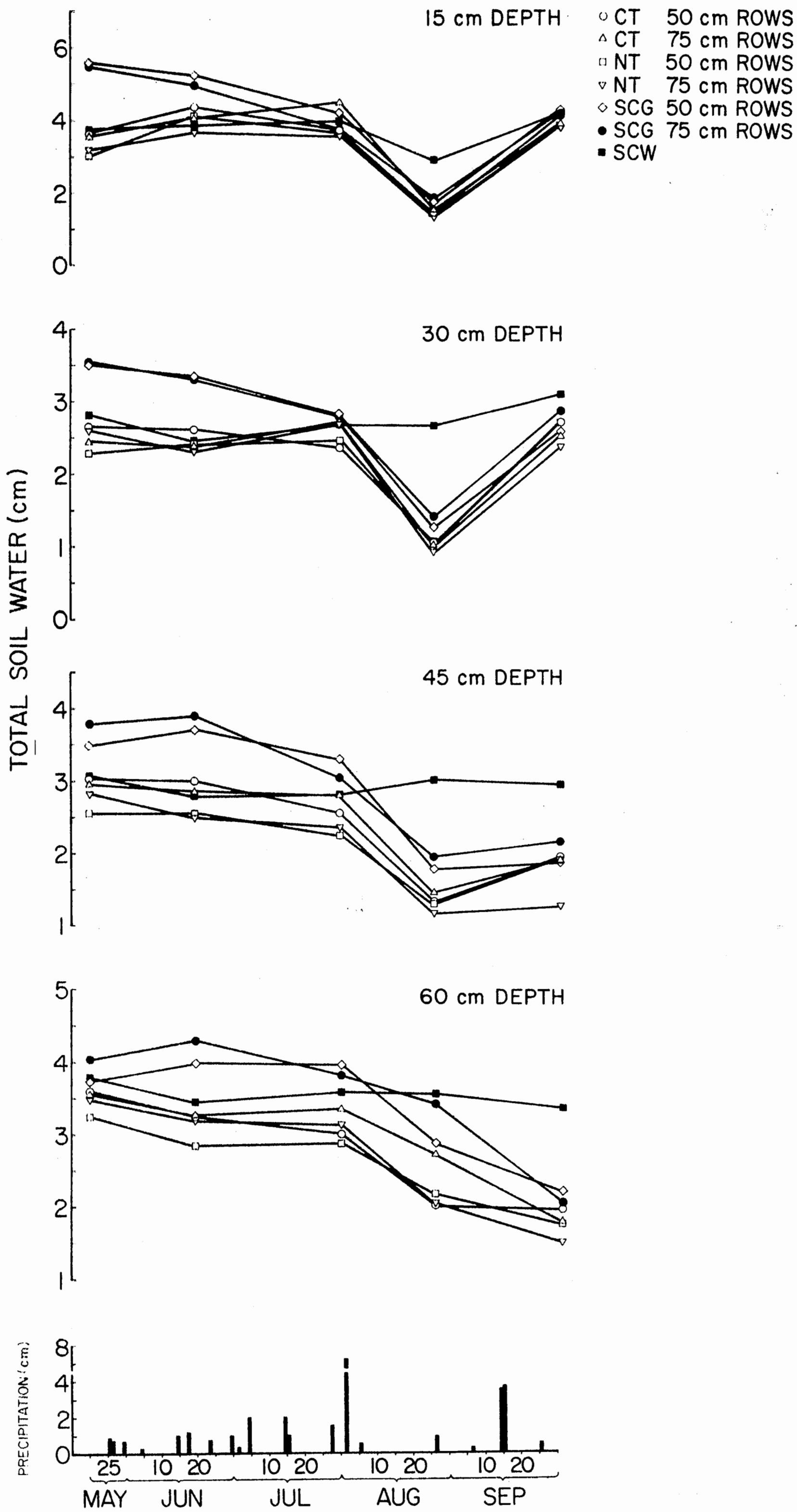

Figure 1. Influence of Tillage and Row Spacings on Total Soil Water at 15, 30, 45 and 60 cm Depths (May 19 - Oct. 1, 1976)

TABLE XII

INFLUENCE OF TILLAGE AND ROW SPACINGS ON TOTAL SOIL WATER (cm) AT 75, 90, 105 AND 120 cm DEPTHS (MAY 19 - OCT. 1, 1976)

Treat-ments	Sampling Dates									
	May 19	June 19	July 29	Aug 25	Oct 1	May 19	June 19	July 29	Aug 25	Oct 1
	75 cm Depth					105 cm Depth				
CT-50	3.69	3.37abc	3.01a	2.59a	2.02a	3.82	3.76	3.52	3.44	2.68a
CT-75	3.79	3.43abc	3.42ab	3.23b	2.18a	3.88	3.86	3.76	3.66	2.80a
NT-50	3.35	2.95a	3.01a	2.67ab	2.17a	3.73	3.58	3.43	3.43	2.78a
NT-75	3.60	3.21ab	3.31ab	2.88abc	2.12a	3.70	3.64	3.60	3.54	2.81a
SCG-50	3.75	3.95b	3.94b	3.34bc	2.51a	3.80	3.92	3.85	3.69	2.95a
SCG-75	3.65	4.11cb	3.89b	3.82bc	2.41a	3.70	3.82	3.64	3.95	3.12ab
SCW	3.76	3.42abc	3.67ab	3.47bc	3.38b	3.82	3.76	3.83	3.71	3.60b
$LSD_{0.05}$	N.S.	0.77	N.S.	0.61	0.58	N.S.	N.S.	N.S.	N.S.	0.58
	90 cm Depth					120 cm Depth				
CT-50	3.76	3.52ab	3.31	3.09a	2.40a	3.98	3.93	3.75	3.74	2.96a
CT-75	3.83	3.66ab	3.60	3.59ab	2.57a	4.06	3.97	3.96	3.87	3.11a
NT-50	3.46	3.20a	3.21	3.09a	2.50a	3.94	3.82	3.78	3.67	3.08a
NT-75	3.56	3.39ab	3.36	3.18a	2.42a	4.03	3.99	3.97	3.95	3.13a
SCG-50	3.74	3.79ab	3.87	3.49ab	2.78ab	4.01	4.04	4.00	3.83	3.22a
SCG-75	3.44	3.98b	3.78	3.99b	2.83ab	3.99	3.99	4.01	3.98	3.37ab
SCW	3.62	3.37ab	3.57	3.40ab	3.32b	4.11	4.06	4.03	3.88	3.87b
$LSD_{0.05}$	N.S.	0.77	N.S.	0.61	0.58	N.S.	N.S.	N.S.	N.S.	0.58

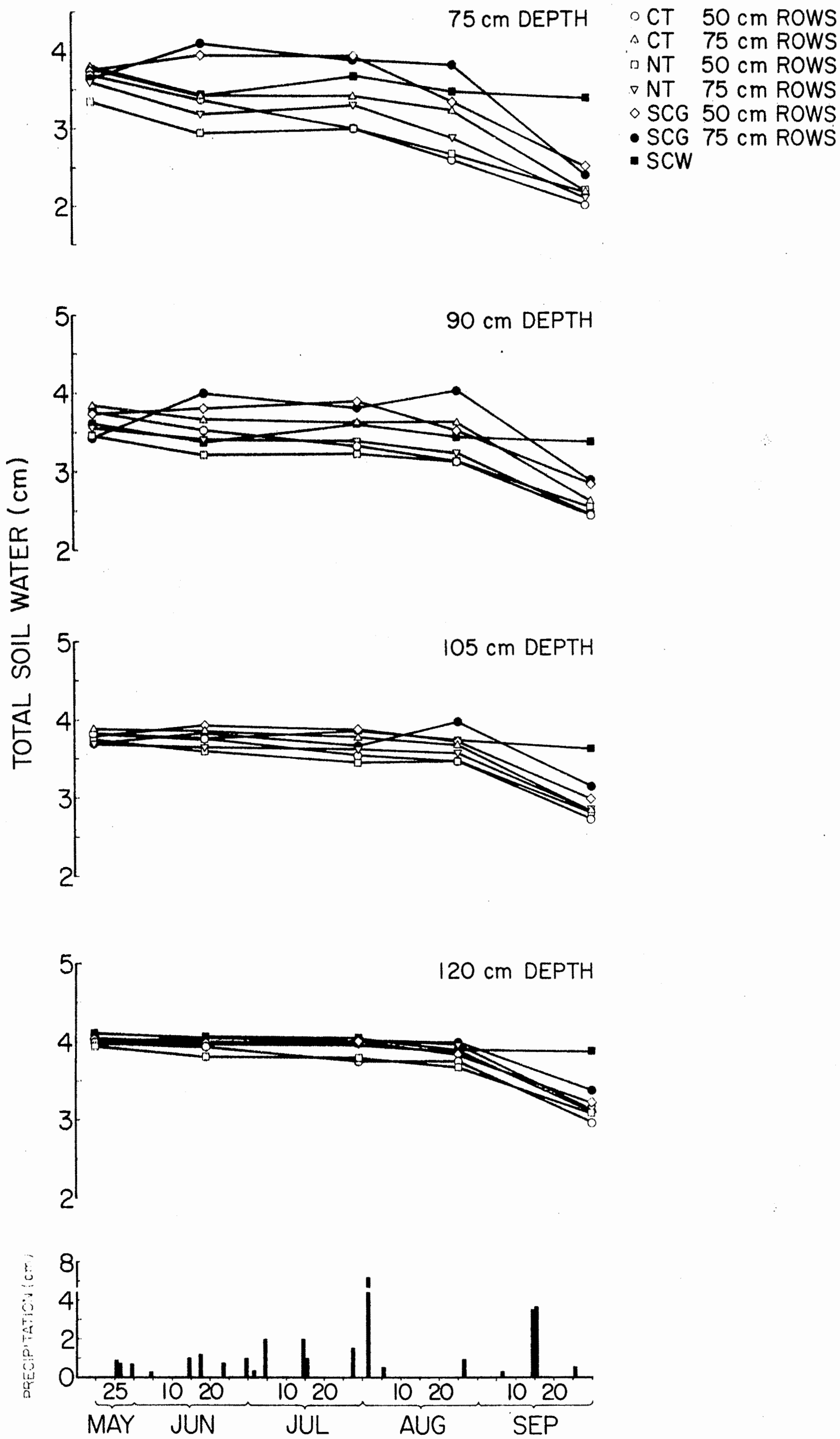

Figure 2. Influence of Tillage and Row Spacings on Total Soil Water at 75, 90, 105 and 120 cm Depths (May 19 - Oct. 1, 1976)

When the double cropped grain sorghum reached the hard dough stage on October 1, 1976, there was no difference between treatments at the surface 15 cm depth. However, the total soil water content from 45 to 120 cm depth in SCW treatment was significantly greater than the others. The SCG-75, however, was comparable to the SCW at depths 90 to 120 cm (Tables XI and XII, Figures 1 and 2).

Total Soil Water in 120 cm Soil Profile

Mean squares from each sampling dates were used to determine the corresponding least significance difference (LSD) values for the total soil water content at each depth. Since the simple F test from the analysis of variance (Table X) did not show any significance between treatments on May 19 and July 29, an LSD test was deleted for these two sampling dates (Tables XI, XII, and XIII).

During the May 19 and June 19 sampling dates, there was significantly higher soil water content on SCG-50 and SCG-75 treatments than CT-50, CT-75, NT-50, NT-75 and SCW because the latter still had wheat on them while the former had been fallow for about nine months (Table XIII and Figure 5). There were no significant differences between the double cropped plots and the SCW in total soil water until the grain sorghum reached the boot stage. After August 25 there was a sharp increase in total soil water on the SCW plots compared to the double cropped plots, since there

TABLE XIII

INFLUENCE OF TILLAGE AND ROW SPACINGS ON TOTAL SOIL WATER (cm) IN 120 cm SOIL PROFILE (MAY 19 - OCT. 1, 1976)

	Sampling Dates				
Treatments	May 19	June 19	July 29	Aug 25	Oct 1
CT-50	28.18	27.78a	25.23	18.68a	20.81ab
CT-75	28.03	27.49a	28.07	21.07ab	20.73ab
NT-50	25.59	25.45a	24.64	18.79a	20.76ab
NT-75	26.94	25.89a	25.96	19.03a	19.46a
SCG-50	31.61	31.98b	29.95	22.00ab	22.39b
SCG-75	31.60	32.37b	28.72	24.37bc	23.02b
SCW	28.65	27.14a	28.09	26.55bc	27.71c
$LSD_{0.05}$	NS	3.53	NS	3.49	2.49

were higher evapotranspiration losses on the later treatments. With the exception of CT-75, there was significantly higher soil water in single crop plots than CT-50, NT-50 and NT-75.

The data also showed that the residual soil water content on all grain sorghum plots, with the exception of NT-75, whether single cropped or double cropped, was similar at the hard dough physiological stage (October 1, 1976). However, there was a significantly larger soil water buildup in the SCW than grain sorghum plots (Table XIII, Figure 5).

Significant differences were not observed among all the double cropped treatments at all sampling dates (Table XIII, Figure 5).

1977 Soil Water Retention

As explained earlier, the 1977 growing season for both wheat and grain sorghum was better than 1976, as far as total rainfall was concerned. The mean squares from analysis of variance of water retention for 1977 showed that treatments were different on May 16 and June 11; and July 18 and August 22 sampling dates at the 0.01 and 0.05 probability levels, respectively. In addition, the total soil water content between treatments was significantly different due to tillage management systems at the 0.01 level of probability on all sampling dates with the exception of August 22, 1977. Again, row spacings had shown no difference throughout the sampling dates (Table XIV).

There were very little differences in total soil water between double cropped wheat plots and SCW in the first 60 cm depth during the May 16 sampling date, but became noticeable at 105 and 120 cm depth (Tables XV and XVI, Figures 3 and 4). However, the total precipitation received during January until early May was about 20% below normal, which could have hampered the magnitude of water recharge for double cropped plots.

The wheat crop was fully ripe on the June 11 sampling date. There was no significant difference in total soil water content between double cropped wheat plots and SCW at 15, 45, 60, 75 and 90 cm depths. Differences were not observed between NT-50 and SCW at 105 and 120 cm depths (Tables XV and XVI, Figures 3 and 4). This gap was closed sharply because there was above normal precipitation received during May, 1977--118.4 vs 127.5 mm (Table I). The results from the 1977 wheat growing season suggest that, with high rainfall, there might be little difference in total soil water content whether single cropped or double cropped.

Grain sorghum was at its collar of the fifth leaf visible physiological stage when water readings were taken on July 18, 1977. There were similar water contents between double cropped plots and SCG-50 and SCG-75 treatments at 15, 30, 120 (and with the exception of NT-75) at 45 and

TABLE XIV

MEAN SQUARES FROM ANALYSIS OF VARIANCE OF WATER RETENTION (cm) FOR 1977 SAMPLING DATES

Source	df	Sampling Dates			
		May 16	June 11	July 18	Aug 22
Replications (R)	2	0.4035	0.1920	3.8738*	9.9735**
Treatments (T)	6	4.0598**	4.2629**	2.7071*	3.1279*
Tam vs Others†	1	0.0356	0.0739	6.5642**	15.7637**
Others	5	4.8647**	5.1007**	1.9357*	0.6008
Tillage Mgmts. (TM)	2	11.6513**	12.5219**	4.4599**	0.7165
Row Spacings (RS)	1	0.2083	0.1302	0.0084	0.0290
TM x RS	2	0.4063	0.1647	0.3751	0.7710
Error A (R x T)	12	0.3081	0.2758	0.6074	0.6698
Depth (D)	7	7.1261**	4.7974**	2.7365**	9.2874**
T x D	42	0.4299**	0.4992**	0.3795**	0.0672
(Tam vs Others) x D	7	0.9062**	0.7474**	0.7380**	0.1223
Others x D	35	0.3346**	0.4496**	0.3079**	0.0562
TM x D	14	0.8076**	1.0267**	0.5296**	0.0672
RS x D	7	0.0192	0.0816	0.2795	0.0425
TM x RS x D	14	0.0190	0.0565	0.1003	0.0520
Error B	98	0.0940	0.1123	0.1576	0.0605

*, **Significant at the 0.05 and 0.01 probability levels, respectively.

†Refers to SCW vs CT-50, CT-75, NT-50, NT-75, SCG-50 and SCG-75.

TABLE XV

INFLUENCE OF TILLAGE AND ROW SPACINGS ON TOTAL SOIL WATER (cm) AT 15, 30, 45 AND 60 cm DEPTHS (MAY 16 - AUG. 22, 1977)

Treatments	Sampling Dates							
	May 16	June 11	July 18	Aug 22	May 16	June 11	July 18	Aug 22
	15 cm Depth				45 cm Depth			
CT-50	2.02a	3.34ab	2.14a	2.08	1.60a	1.67a	3.12ab	1.40a
CT-75	2.11a	3.37ab	2.15a	2.10	1.61a	1.68a	2.88ab	1.47a
NT-50	2.35a	3.23ab	2.25a	2.10	1.49a	1.44a	2.86ab	1.68ab
NT-75	1.83a	2.81a	2.09a	2.01	1.13a	1.25a	2.42a	1.27a
SCG-50	3.78b	4.20c	2.13a	2.13	3.04b	3.68b	3.35b	1.45a
SCG-75	3.57b	3.53b	2.05a	2.14	3.11b	3.67b	2.87ab	1.46a
SCW	1.85a	3.37ab	3.94b	2.61	1.39a	1.38a	3.10ab	2.13b
$LSD_{0.05}$	0.58	0.60	0.77	N.S.	0.58	0.60	0.77	0.63
	30 cm Depth				60 cm Depth			
CT-50	1.24a	2.33b	2.40ab	1.22a	2.24ab	2.11a	2.94abc	1.86ab
CT-75	1.14a	1.95ab	2.29ab	1.15a	2.23ab	2.08a	2.78ab	2.12ab
NT-50	1.23a	1.82ab	2.38ab	1.40ab	2.23ab	2.02a	2.62ab	2.28ab
NT-75	1.00a	1.76ab	2.13a	1.23a	1.89a	1.82a	2.37a	1.65a
SCG-50	2.61b	3.34c	2.39ab	1.17a	2.95bcd	3.27b	3.68bcd	2.29b
SCG-75	2.65b	3.33c	1.96a	1.27a	3.16cd	3.62b	3.89bcd	2.18ab
SCW	1.10a	1.69a	3.05b	1.92b	2.48bc	2.15a	3.32bcd	3.06c
$LSD_{0.05}$	0.58	0.60	0.77	0.63	0.58	0.60	0.77	0.63

TABLE XVI

INFLUENCE OF TILLAGE AND ROW SPACINGS ON TOTAL SOIL WATER (cm) AT 75, 90, 105 AND 120 cm DEPTHS (MAY 16 - AUG. 22, 1977)

	Sampling Dates							
Treatments	May 16	June 11	July 18	Aug 22	May 16	June 11	July 18	Aug 22
	75 cm Depth				105 cm Depth			
CT-50	2.38a	2.32	2.51ab	2.17a	2.91a	2.85a	2.91a	2.59a
CT-75	2.45ab	2.43	2.49ab	2.39a	2.90a	2.90ab	2.87a	2.71ab
NT-50	2.42a	2.35	2.35a	2.57a	2.99a	3.01ab	2.89a	2.99ab
NT-75	2.28a	2.25	2.37ab	2.13a	2.77a	2.76a	2.90a	2.63a
SCG-50	2.77ab	2.73	3.22bc	2.62a	3.24ab	3.08ab	3.15ab	2.84ab
SCG-75	2.79ab	2.85	3.86bc	2.61a	3.20ab	3.24ab	3.87b	3.28bc
SCW	3.01b	2.63	3.10abc	3.49b	3.61b	3.49b	3.56ab	3.89bc
$LSD_{0.05}$	0.58	N.S.	0.77	0.63	0.58	0.60	0.77	0.63
	90 cm Depth				120 cm Depth			
CT-50	2.61a	2.58	2.62a	2.35a	3.26a	3.15a	3.14	2.84a
CT-75	2.74ab	2.70	2.66a	2.50a	3.19a	3.17a	3.11	2.85a
NT-50	2.79ab	2.69	2.66a	2.79a	3.26a	3.24ab	3.16	3.15a
NT-75	2.49a	2.47	2.56a	2.36a	3.08a	3.11a	3.48	3.12a
SCG-50	2.95ab	2.95	3.08a	2.77a	3.25a	3.30ab	3.42	3.03a
SCG-75	3.03ab	3.03	3.91b	2.98a	3.44ab	3.48ab	3.76	3.47ab
SCW	3.27b	2.99	3.16a	3.68b	3.85b	3.81b	3.82	4.03b
$LSD_{0.05}$	0.58	N.S.	0.77	0.63	0.58	0.60	N.S.	0.63

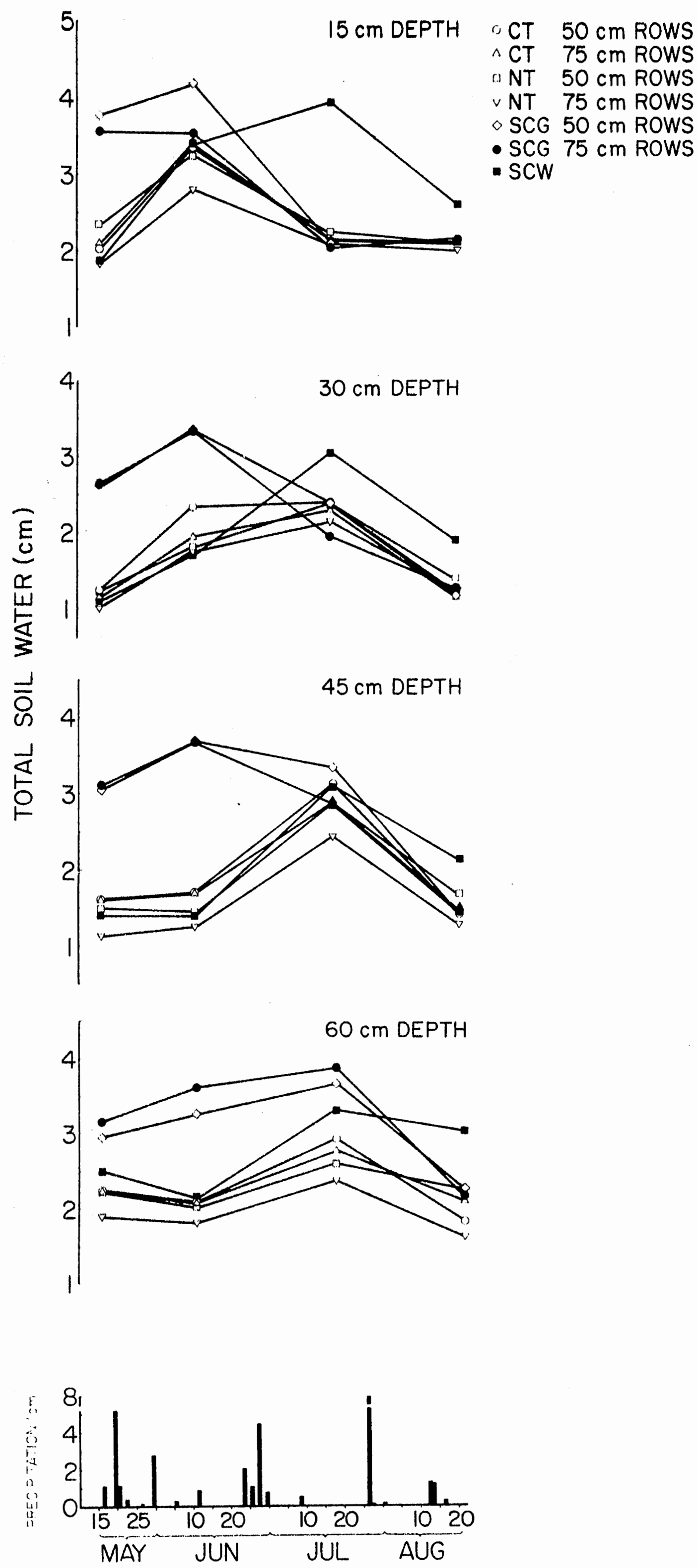

Figure 3. Influence of Tillage and Row Spacings on Total Soil Water at 15, 30, 45 and 60 cm Depths (May 16 - Aug. 22, 1977)

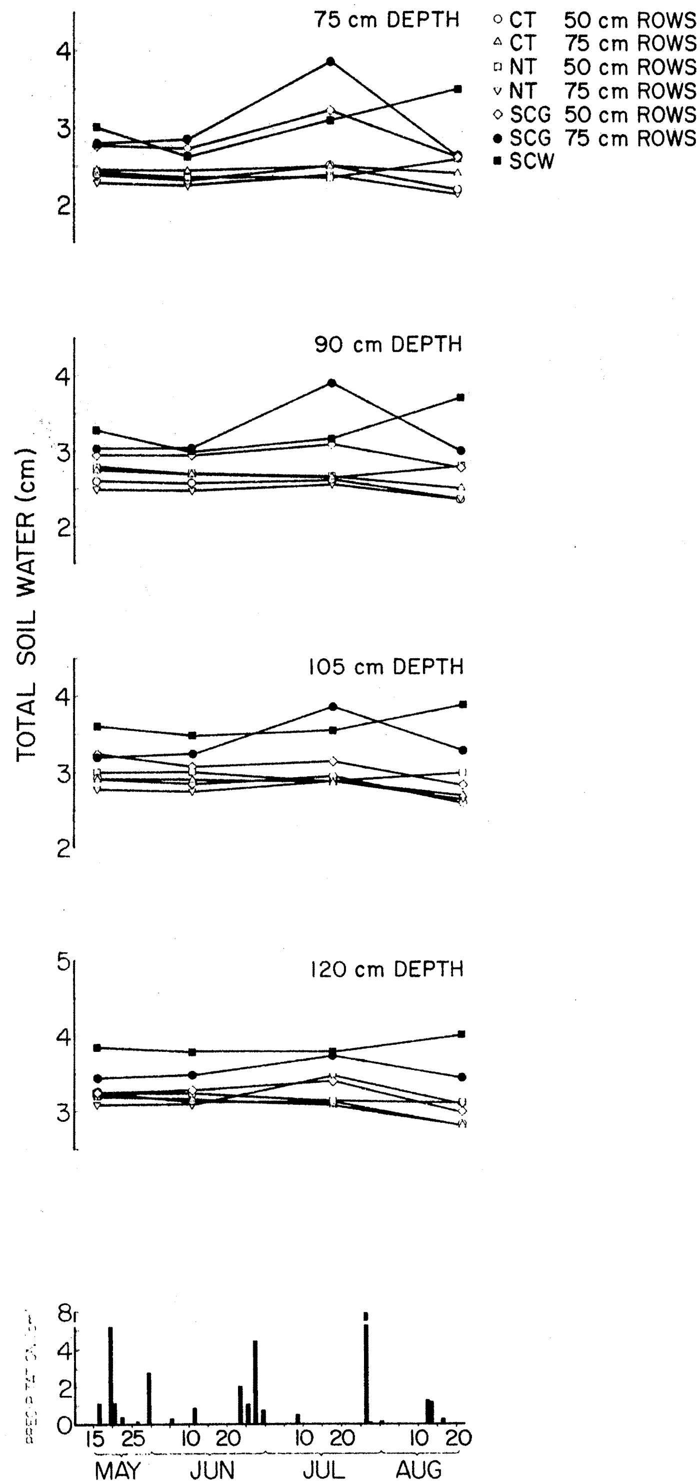

Figure 4. Influence of Tillage and Row Spacings on Total Soil Water at 75, 90, 105 and 120 cm Depths (May 16 - Aug. 22, 1977)

and 60 cm depths as well. The variation could have narrowed still further had it not been due to the 15% below normal precipitation received during June and July. Moreover, 95% of the July precipitation occurred after the July 18 sampling date.

August 22 was the last sampling date in 1977. During that period, the grain sorghum had reached the boot stage of growth. There were no significant differences between the double cropped grain sorghum treatments vs SCG-50 and SCG-75 at 15, 30, 45, 60 and, except for SCG-50 and NT-75, at 75, 90 and 120 cm depths. In addition, CT-75, NT-50, SCG-50 and SCG-75 showed little difference at the 105 cm depth (Tables XV and XVI, Figures 3 and 4).

Total Soil Water in 120 cm Soil Profile

The overall total soil water in the 120 cm soil profile was compared to determine the influence of tillage and row spacings for 1977 growing seasons. There were no significant differences between the double cropped treatments at all sampling dates (Table XVII). Significance was not observed between SCW and double cropped treatments on May 16, June 11 and July 18, except NT-75, which had lower soil water content at all stages. Significantly, higher total soil water was obtained during May 16 and June 11 sampling dates on SCG-50 and SCG-75 plots as compared with other treatments because they had been fallow

TABLE XVII

INFLUENCE OF TILLAGE AND ROW SPACINGS ON TOTAL SOIL WATER IN 120 cm SOIL PROFILE (MAY 16 - AUG. 22, 1977)

	Sampling Dates			
Treatments	May 16	June 11	July 18	Aug 22
CT-50	18.26ab	20.35ab	21.78ab	16.51ab
CT-75	18.37ab	20.28ab	21.23ab	17.29a
NT-50	18.76ab	19.80ab	21.13ab	18.96a
NT-75	16.47a	18.23a	20.32a	16.40a
SCG-50	24.59c	26.55c	24.42b	18.20a
SCG-75	24.95c	26.75c	26.17bc	19.39a
SCW	20.56b	21.51b	27.05bc	24.81b
$LSD_{0.05}$	2.79	2.64	3.92	4.12

for some time. But this difference was narrowed by July 18. When the grain sorghum reached the boot stage on August 22, there were no significances shown in all treatments whether single cropped or double cropped. However, there was a much larger water reserve in the 120 cm soil profile among SCW treatments than the grain sorghum plots (Table XVII and Figure 6).

There was a similar soil water content in the 120 cm soil profile throughout the four sampling dates among all the double cropped plots in 1977 (Table XVII and Figure 6).

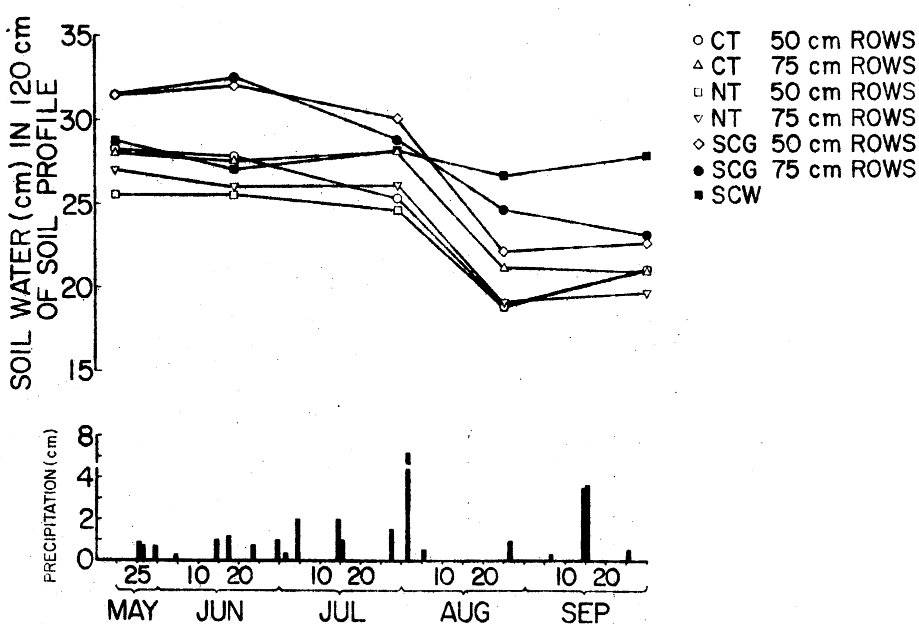

Figure 5. Influence of Tillage and Row Spacings on Total Soil Water in 120 cm Soil Profile (May 19 - Oct. 1, 1976)

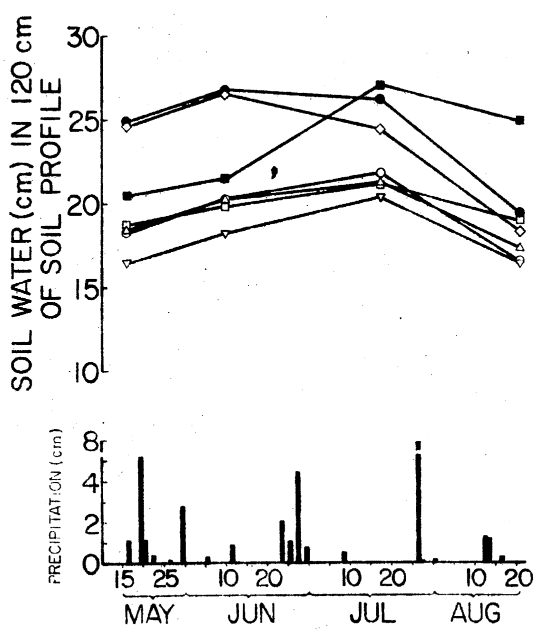

Figure 6. Influence of Tillage and Row Spacings on Total Soil Water in 120 cm Soil Profile (May 16 - Aug. 22, 1977)

CHAPTER V

SUMMARY AND CONCLUSIONS

A two year field study was conducted on a wheat followed by grain sorghum double cropping system on a silty clay loam soil at the Oklahoma Vegetable Research Station near Bixby, Oklahoma. Three tillage management systems (conventional, minimum and no-till) for the double cropped sorghum were compared with single crop conventional at two row spacings (50 and 75 cm). Wheat was established using conventional tillage systems in all treatments, including single crop plots. The influence of tillage methods and row spacings was evaluated on yields and total volumetric soil water content at different physiological stages of growth. Volumetric soil water content readings were not monitored on minimum till treatments.

When both single and double cropped grain sorghum treatments were planted at the same date, there were little differences in yields due to tillage methods. Higher yields, however, resulted where narrow rows were used in both years. Yields obtained from minimum till double cropped treatments planted at 50 cm rows were 16% higher than the single crop grain sorghum at the same row spacing in 1976. The highest yield obtained from the former was attributed to tillage x row spacing interaction which was significant at the .01 level.

The 1977 wheat data showed that significantly lower yields (20.92 vs 32.55 q/ha) were obtained on the double cropped wheat treatments compared to the single cropped wheat. The decrease in yields were in part probably due to the immobilization of soil nitrogen during the initial decomposition process created by the presence of heavy grain sorghum residues. When the wheat yields from double cropped treatments were compared, higher values were obtained where grain sorghum had been grown in narrow rows during the preceding summer. Tillage methods, however, had no significant residual influence on the yields of double cropped wheat.

The data for the total volumetric soil water content in 120 cm soil profile showed no significant differences between tillage methods and row spacings on the double cropped treatments throughout the two year sampling dates. The total soil water content was similar in all the grain sorghum treatments, including single cropped plots, at the hard dough physiological stage of growth in 1976; and at the collar of the fifth leaf visible stage in 1977, with the exception of NT-75 in both years. However, there was a buildup of about seven cm more water in single crop wheat plots than double cropped treatments at the time of the last sampling in both 1976 and 1977. Following wheat harvest, about 21 cm of precipitation was received in the area, of which only 33% was stored in the soil profile and the other 67% being lost mainly as surface evaporation.

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VITA

Girma Makonnen

Candidate for the Degree of

Master of Science

Thesis: THE INFLUENCE OF TILLAGE AND ROW SPACINGS ON YIELDS AND SOIL WATER CONTENT IN A WHEAT GRAIN SORGHUM DOUBLE CROPPING SYSTEM

Major Field: Agronomy

Biographical:

Personal Data: Born in Shirka, Arssi, Ethiopia, May 28, 1950, the son of Ato Makonnen Alemu and Woizero Yirgedu Hailu.

Education: Graduated from Ras Dargei High School, Assela, Arssi, July, 1968; received the Bachelor of Science degree from National University, Alemaya, Ethiopia, in July, 1973; completed the requirements for a Master of Science degree in May, 1978, from Oklahoma State University.

Professional Experience: Worked as Soil and Water Conservation supervisor in the Ministry of Agriculture, EPID, 1973-75.