THE EFFECTS OF IRRIGATION AND CROPPING SYSTEMS ON YIELDS OF WHEAT, SOYBEANS, AND GRAIN SORGHUM IN EASTERN OKLAHOMA

By

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CHAPTER I

INTRODUCTION

The increase in the demand for food crops as a result of a continuous growth in the world's population must be met by improving productivity on arable land each year. This goal may be achieved through double cropping systems, which present a means of increasing productivity per unit land area per year.

Double cropping is the growing of two successive crops on the same field during one year. It offers an opportunity to increase production with more efficient utilization of land, labor, machinery, climatic resources (rainfall, frost-free days, and sunlight) and other capital investments. In eastern Oklahoma, favorable climatic conditions and soils have the potential for double cropping that may enable farmers to increase their profits.

New developments and improvements within the herbicide industry, with new or improved no-tillage practices, crop varieties, planting techniques, and the availability of farm machinery and equipment make double cropping systems possible for many farmers. As a result of these developments, interest in double cropping has increased. Small grains particularly wheat followed by summer crops, usually soybeans or grain sorghum, are commonly used in double cropping systems in eastern Oklahoma.

The success or failure of double cropping in this part of Oklahoma is primarily dependent upon the amount and distribution of rainfall through the summer months. Because rainfall is often erratic in this area supplementary irrigation may prove to be profitable.

The objective of this study was to compare yields of mono- and double cropped soybeans and grain sorghum when grown under both irrigated and rainfed conditions in eastern Oklahoma.

CHAPTER II

LITERATURE REVIEW

Double Cropping

Double cropping is not a new concept, but instead a century old intensive farming technique that maximizes productivity (Lewis and Phillips, 1976). Papendick et al. (1973) reported that recent food shortages and prospects of future inadequate food supplies have promoted accelerated interest in double cropping.

Double cropping means producing two crops on the same acreage in one year (Wendke and Nave, 1979). In many areas this is accomplished by growing a winter small grain crop followed by a summer feed grain or soybean crop (Gallaher et al., 1976; McKibben and Oldham, 1973).

Success of a double cropping systems depend upon weather factors. Camper et al. (1972) stated that weather plays a major role each year in determining both yield and quality of grain sorghum and soybeans when double cropped. McKibben and Pendleton (1968) stated that the amount and distribution of rainfall in mid-summer will dictate the success of double cropping systems. Crabtree and Rupp (1980) stated that in regions with adequate frost-free days to permit double cropping, water is often the most limiting factor in producing the second crop. McKibben and Pendleton (1968) reported that the major problem in southern Illinois in producing two crops in one year on the same field is that rainfall in late June and early July is often too low for good germination and vigorous early growth. Due to that factor, producing a second crop in 1967 failed, whereas in 1972, the summer rainfall was above normal, and double cropping was successful. Sanford (1982) obtained similar results in 1977 when double cropped soybeans failed due to inadequate rainfall in late spring and early summer.

Even though climatic conditions, such as number of frost-free days and distribution of rainfall, favor double cropping management systems in many areas, time lapse between harvesting the first crop and planting the second crop is critical (Touchton and Johnson, 1982). In the Northern Great Plains, the growing season is too short and precipitation is insufficient for many double cropping systems, however, it is possible to produce a crop of early barley and then an oat crop for hay (Gomm et al., 1976).

Double cropped soybeans after wheat can be an economical practice in Nebraska, if soil moisture is adequate and time between wheat harvest and frost is adequate for the crop to mature (Williams et al., 1972). Camper et al. (1972) reported that maize and corn in Virginia were severely damaged by frost when double cropped after barley and planted in July. Selection of the particular small grain species depends upon the intent of utilization. Wheat can be grown either for grain or silage (Lewis and Phillips, 1976). Farmers interested in cash crops will usually choose soybeans as a second crop, while dairy farmers wanting livestock feed will grow corn or grain sorghum as a second crop (McKibben and Oldham, 1973).

Interest has been stimulated in double cropping systems by recent development of new early-maturing shorter cultivars with high yield, particularly soybeans and small grain, and newly developed, more effective herbicides. Improvement of no-tillage planting equipment and techniques also encourages the acceptance of double cropping systems (Lewis and Phillips, 1976; Crabtree and Rupp, 1980). Some management practices that enhance the success of double cropping are: 1) establishment of an excellent stand of well fertilized small grains, which helps to control weeds until the crop is harvested; 2) early removal of small grains to increase the chance of maturity of the second crop; 3) use of the proper combination of herbicides; 4) correct cultural techniques, including narrow-row spacing and in some cases high plant populations; 5) crop varieties of proper maturity; 6) sufficient moisture; 7) planting the second crop immediately after removal of the first crop; and 8) operators skilled in management (McKibben and Oldham, 1973).

Crabtree and Rupp (1980) stated that growing two successive crops on the same land in one year can result in more efficient utilization of climatic resources, land, labor, machinery, and other capital investment. Sanford (1982) reported the advantages of a double cropping system to be: 1) increased profits resulting from more efficient use of land and other investments; 2) reduced soil and water losses by having the soil covered with a plant canopy most of the year; and 3) increased use of soil, water, and energy-conserving tillage methods.

Double cropping systems such as soybeans following wheat are efficient and common in much of the eastern United States, from Georgia to southern Illinois, and west to Oklahoma (Clapp, 1974; Crabtree and Rupp, 1980; Sanford, 1979; Touchton et al., 1980). Soybeans double cropped after wheat is a common practice in Indiana (Swearingin, 1974) and in other parts of the midwest (Wendte and Nave, 1979). Because of the predicted increase in demand for proteins and oil (both obtained from soybeans), the motives for using soybeans as a second crop are economically as well as agronomically desirable (Wendt and Nave, 1979). In the south, Sanford (1982) found that wheat and soybeans were more compatible crops; the soybeans-wheat double cropping system was nearly three times as profitable as a grain sorghum-wheat system. Camper et al. (1972) reported that double cropping is a common practice in eastern Virginia, and is accomplished by following winter barley with a summer crop of soybeans. For this region soybeans planted by June 30 produced yields of very good quality, however, yields after mid-July plantings were greatly reduced.

Crabtree and Rupp (1980) reported that double cropping systems result in more total grain production, but yields of the monocrop were usually reduced. Thill et al. (1978) and Knapp and Knapp (1978) reported that when compared to wheat planted at optimal planting date, late planted wheat produced lower grain yields because it extracted a lesser amount of water from the soil, developed a less extensive root system and fewer tillers, which resulted in fewer heads. Hinkle (1975) reported that the average yield of double cropped soybeans in Arkansas in 1970 was 37.2 bushels per acre. A delay of 12 days in planting time resulted in a decrease of 6.2 bushels per acre. Hinkle also showed that soybean yields are reduced when the planting date is later than June 10, because germination after the middle of June does not provide the soybean plant enough time for good vegetative growth.

In Illinois when soybeans were double cropped after wheat the yields of soybeans declined 50 kg/ha each day planting was delayed in late June or early July (Hoeft et al., 1975). Major factors contributing to yield reductions of late-planted soybeans were uncertainty of rainfall in late June and early July for good germination and early growth, and frost before crop maturity (McKibben and Pendleton, 1968). To permit earlier soybean planting, Hoeft et al. (1975) suggested harvesting wheat at 19 to 22% moisture, which allowed planting 4 to 7 days earlier than with normal harvesting.

Planting barley as the small grain crop often allows for earlier planting of the second crop. For example, Barsoy barley has a two-week advantage over wheat in maturity. This advantage showed in higher soybean yields following barley as compared to wheat in Kentucky (Herbek, 1974). In Georgia, the harvesting of the small grain crop early, followed by artificial drying of the grain enables earlier planting of the second crop. However, when full season soybeans are grown, the following wheat crop is often planted later than the optimum date for maximum yield (Touchton and Johnson, 1982). Sanford (1979) in Mississippi and Clapp (1974) in North Carolina reported that late wheat planting can be avoided by overseeding wheat into soybeans that have not yet reached maturity.

Sanford (1982) found that yields of wheat when double cropped after soybeans were higher than when double cropped after grain sorghum. These researchers attributed the higher yield of wheat following soybeans to the contribution by soybeans to the nitrogen supply and improved tilth. Yield of wheat was not significantly affected by the method of tillage used for the previous crop (Sanford et al., 1973). Touchton and Johnson (1982) reported that wheat following no-tillage soybeans yielded significantly less than wheat planted after conventionally tilled soybeans.

Tillage

The art of tillage began when man first domesticated and cultivated plants. Since that time, various tillage practices have evolved, ranging from the primitive hoe to the current complex conventional, minimum, and no-tillage systems (Blake, 1963).

Any manipulation that changes the physical properties of the soil may be considered as tillage (Schafer and Johnson, 1982). The most critical period in a plant's life cycle is that of seed germination and seedling establishment because these two processes are influenced by environmental conditions (Unger and Stewart, 1976). Soil is tilled to provide suitable conditions not only for optimum plant growth but also for necessary field operations, e.g., planting and harvesting (Baeumer and Bakermans 1973). Troch et al. (1980) stated the following reasons for tilling the soil: 1) preparation of seed and root bed; 2) control of weeds; and 3) management of soil surface conditions that favor water infiltration and erosion control. To achieve the ideal environmental condition for a crop, we must know the plant's basic requirements for oxygen, water, nutrients, and temperature. Black and Siddoway (1979) and Unger and Stewart (1976) reported that, besides these basic requirements, there are some secondary requirements to assure good seed germination and seedling establishment, including: 1) adequate soil aeration for gaseous exchange in the seed and root zone; 2) adequate seed-soil contact to permit water flow to seeds and seedling roots; 3) a noncrusted soil to permit seedling emergence; 4) a low density soil that permits root elongation and proliferation; 5) an environment that provides adequate light to the seedling; 6) an environment that affords protection against wind and water erosion; and 7) a pest-free or pest controlled environment. Larson (1962) reported that managing soil and water and providing the proper soil environment for the plant seedling overshadows weed control as a primary objective of tillage. Through the years, various practices and tillage systems have been developed to reduce potential hazards to crop production during seed germination and seedling establishment. Thus, tillage systems should be designed to meet the particular requirements of the soil, crop, and climate. Tillage may influence the movement of water into and the retention of water within the soil profile (Larson, 1962; Soane and Pidgeon, 1975).

No-Tillage

No-tillage systems are an extreme form of conservation tillage in which all the plant residue remains on the soil surface. No-tillage has been concisely defined as placing the crop seed into the soil by a device that opens a trench or slot through the sod or previous crop residue only sufficiently wide and deep to receive the seed and to provide satisfactory seed coverage (Crosson, 1981; Young, 1973). Sanford et al. (1973) defined 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. In no-tillage systems, herbicides are used to control existing vegetation, and the new crop is planted directly into the soil with no plowing or other tillage (Clapp, 1972). The key to successful no-tillage is satisfactory control of noncrop vegetation with herbicides without injury to the crop (Young, 1973).

Gregory et al. (1970), Hargrove et al. (1982) and Hovermale et al. (1979) reported the advantages of no-tillage systems as follows: 1) reduced soil and moisture loss; 2) ability to use sloping land for grain or silage production; 3) ability to plant under wetter soil conditions; 4) yields equal to or higher than those from conventional tillage; 5) better maintenance of the soil's physical condition by elimination of plowing and land preparation; 6) time saved in planting the second crop; and 7) reduced labor expenditures and other production costs. Several million acres of grain crops are now produced by no-tillage in North America (Phillips and Young, 1973). Baeumer and Bakermans (1973) stated that no-tillage is a good alternative to the conventional tillage systems when soils are subject to wind and water erosion, time of tillage operation is limited, and requirements of energy and labor are excessive. Row crops can be grown on sloping land previously considered unsuitable or marginal for conventional tillage. Recent changes in tillage systems, progressing from conventional (intensive) tillage to reduced tillage and finally to no-tillage have been motivated by recent developments in herbicides and a desire to control erosion and to reduce operating costs (Black and Siddoway, 1979).

Harrold et al. (1970) have recorded that plot experiments with natural and artificial rainfall, along with watershed tests, show that no-tillage significantly reduces soil erosion compared with conventional ploughing and clean-tillage practices. Harrold and Edwards (1972) emphasize the soil-conserving value of no-tillage production, it was observed that a 14 cm rainstorm eroded 50.7 mt/ha from ploughed, clean tilled, sloping-row watershed (6.6% slope), 7.2 mt/ha from ploughed clean-tilled contour-row watershed (5.8% slope) and only 0.07 mt/ha from no-till contour-row watershed (20.7% slope).

Tillage systems may influence the retention and movement of water in the soil profile (Soane and Pidgeon, 1975). Mulch appears to influence crops in two ways - soil moisture and soil temperature. First, mulch increases the level of soil water storage. Mulch also conserves water by increasing infiltration and reducing runoff and evaporation (Blevins et al., 1971; Greb et al., 1970; Jones et al., 1969; Robertson et al., 1976; Unger et al., 1971). The mulch physically absorbs rain drop impact energy; thus slaking and sealing of soil surface is prevented or at least retarded (Unger and Phillips, 1973). Therefore, no-tillage is often employed with a heavy surface mulch of plant residues to increase infiltration and decrease erosion hazards (Harrold et al., 1970), but in Britain, the presence of mulch is considered undesirable (Soane and Pidgeon, 1975). Papendick et al. (1973) concluded that for dry land, a soil mulch is determintal to absorption of overwinter precipitation, but reduces evaporation of stand water during the summer as compared with unmulched soil. He also noted a slight increase in water retention over summer in the upper 90 cm of soil when the mulch depth increased. On silt loam with an 8 to 10% slope that was planted in row crops using a no-tillage system, reduction of runoff ranged from 1/2 to 1/6 of the amount observed under clean tillage (Harrold and Edwards, 1972; Jones et al., 1969).

The purely protective effect of residue cover may influence the rate of evaporation. Bond and Willis (1969), Papendick et al. (1973) observed that the evaporation rate decreases as the amount of mulch increases, resulting in a higher mean volumetric moisture content in the upper soil layer when compared to conventional tillage. No-tillage generally conserves soil moisture (Blevins et al., 1971).

Plant growth and yield responses to the tillage system depend primarily on water conservation practices. Under no-tillage conditions, the decreased evaporation, reduced runoff, and greater ability of the soil to store moisture results in a water reserve which can carry the crop through periods of short-term drought without detrimental moisture stress developing in the plants (Blevins et al., 1971). Soybeans can be produced economically when planted in winter wheat stubble if adequate moisture is available from rainfall or irrigation to establish and develop the crop (William et al., 1972).

In the Texas panhandle, under no-tillage, plants generally emerged faster, grew taller and matured up to 5 days earlier compared to tilled plots. Slower drying of the soil surface and improved microclimate in no-tillage plots during seedling emergence, apparently aids in a faster start and resulted in a higher yield average of 5,690 kg/ha of grain sorghum compared to that of a conventional tillage system, which produced 5,070 kg/ha (Allen et al., 1975).

Total water use efficiency was higher for no-tillage than for conventional tillage corn populations in West Virginia. The greater water use efficiency with no-tillage can largely be attributed to early season residue effects on slowing evaporation loss and increasing growth and yield (Bennett et al., 1973). Inadequate seedbed water at planting time is a major limiting factor to early establishment of any crop (Papendick et al., 1973).

Smith and Camper (1975) reported that both size and quality of soybean seed are affected by genetic and environmental conditions. Moisture stress during the seed maturation stage can result in poor seed quality. Green et al. (1965) and Tyler and Overton (1982) stated that in the hot dry growing season, seed produced under no-tillage usually appeared to be of better quality than those produced under conventional tillage, as a result of soil water availability. Secondly, the amount of mulch covering the soil surface influences the soil temperature. During the growing season, untilled soil or merely mulched soils were observed to be cooler than tilled soil, especially at planting time in early spring (Unger and Stewart, 1976).

No-tillage saves both time and energy. Allen et al. (1975) reported no-till required only 1/5 as much time between crops to prepare and plant a second crop as conventional tillage required, and no-till reduced fuel use by 55%. As a result of lower evaporation rate and lower soil temperature with conservation tillage, soil crusting is reduced (Army et al., 1961; Siddoway, 1963). Disadvantages of no-tillage systems include: 1) requires special planting equipment; 2) results in low soil temperatures and slows early growth in cold regions; 3) weed control problems are greater due to interference of crop residues with herbicides; 4) poor stands may limit yield; and 5) residue may harbor insects and rodents.

Graffis et al. (1973) and Gregory et al. (1970) stated that one of the requirements for successful no-tillage systems is a good weed control program. The problem of how to eradicate persistent weeds with continuous application of no-tillage has yet to be solved. Incomplete weed control is the principal problem for further adaptation of no-tillage

(McKibben and Oldham, 1973). Weed control was a major factor in yield reduction when soybeans and grain sorghum were planted into small grain stubble, because both soybeans and grain sorghum were stressed by competition from weeds (Sanford et al., 1973).

Studies conducted in Arkansas by Hinkle (1975) showed that yields of a second crop planted by a no-tillage method and grown without tillage resulted in comparable yields to conventional tillage when conditions were favorable for good chemical weed control. However, when little or no weed control by herbicides was used with the no-tillage method, yields were reduced. High yields and improvements in the field of herbicides have obviously become important reasons for many growers to change to no-tillage crop production (Young, 1973).

In a Mississippi study, two year yield averages of grain sorghum were 3,250 kg/ha for no-tillage and 3,870 kg/ha for conventional tillage. This difference in yield was due mainly to a lack of weed control by herbicides on no-tilled plots. In the third year, when nutsedge was controlled by hand hoeing, no-till and tilled sorghum yields were 5,072 and 4,330 kg/ha, respectively. Straw tends to intercept chemicals, thereby decreasing herbicide efficiency. Dry wheat straw also tends to impede performance of standard cultivation equipment (Sanford, 1982).

McDowell and McGregor (1980) stated that surface application (without incorporation) of fertilizers and lime is a common practice in reduced tillage crop production. The lack of fertilizer incorporation in the soil has been shown to increase the amount of soluble nutrients measured in runoff (Whitaker et al., 1978). Studies in Mississippi indicated that the total plant nutrient losses (sediment plus solution) decrease if conservation practices are a part of soil management, but that concentration of solution phase nutrients, particularly phosphorus (P), magnesium (Mg), calcium (Ca), and potassium (K), may be higher in runoff from reduced tillage, while the sediment concentration is low (Bennett, 1977; Holt et al., 1973).

Shear and Moschler (1969) reported high accumulations of P (238 ppm) in the soil surface (5 cm) in a no-tillage treatment compared with 59 ppm in the same soil layer depth in conventional tillage systems. Some reports (Estes, 1972) suggest that there is no difference between availability of surface-applied and incorporated P, but Moschler and Martens (1975) have reported a higher P efficiency with no-tillage than with conventional tillage. Blevins et al. (1977), Sanford et al. (1973), and Bennett (1977) reported that organic matter and organic nitrogen increased significantly in the top layer (5 cm) of the soil by continuous practice of no-tillage. However, the nutrient status of soil under no-tillage management appeared at least equal, if not superior, to that under conventional tillage.

As a result of the surface application of fertilizers, more frequent lime applications may be needed to prevent a rapid development of an acid layer near the soil surface due to the accumulation of organic matter (Bennett, 1977). However, Hargrove et al. (1982) reported that pH values are lower below the soil surface layer (5 cm) in no-tillage, due to the ineffectiveness of the surface application of lime. Hargrove et al. (1982) and Blevins et al. (1977) stated that in the treatments which received little or no disturbance (no-tillage) the soil pH below the top (5 cm) dropped compared to the top soil. Plots which were conventionally plowed at least once a year, on the other hand, resulted in more homogeneous soil with respect to pH.

Unger (1978) stated that soil temperature is affected by many factors, including air temperature, soil water content, soil structure, soil texture, and type and amount of vegetative cover. Since conservation tillage directly influences many of these factors, soil temperature is affected. Surface residues associated with reduced or no-tillage systems often result in lower spring and summer soil temperature when compared to fallow soil (Taylor, 1967; Unger, 1978). Therefore, favorable temperature for germination and emergence may occur up to 7 days later in a no-tillage seedbed. Planting may be delayed 6 or 7 days with no-tillage systems used in northern latitudes of the U.S.A. (Unger and Stewart, 1976).

Although lower temperatures may delay planting in the spring, lower temperatures under surface residues in the summer may beneficially influence a late-planted crop or crops growing during hot periods (Allen et al., 1975; Rockwood and Lal, 1974). In Nigeria the temperature was 41°C at the 5 cm depth 2 weeks after planting grain sorghum in clean tilled soil. Where the sorghum was no-tillage planted through 1 to 2 cm of crop residue, the temperature reached only 31°C. The higher temperature reduced germination and seedling vigor. Yields were 50% greater with no-tillage than with conventional tillage because lower temperatures reduced plant water stress (Rockwool and Lal, 1974).

Adams (1962) proposed that early planting of grain sorghum in Central and Southern Texas is desirable for avoiding yield decrease from summer heat, drought, and damage by sorghum midge. However, cooler temperatures due to a high quantity mulch covering the soil, resulted in 2 to 5 days delay in sorghum emergence and slower early plant growth. Surface residues generally reduce soil temperatures in the spring and summer, which influences soil nitrogen mineralization (Sanford et al., 1973). This reduces soil nitrate accumulation during fallow when wheat straw residue exceeds 3,000 kg/ha (Smika et al., 1969).

For rapid water imbibition, seeds must adequately contact moist soil. Good seed-soil contact prevents seed from being pushed out of the soil by the elongating radical. Seedlings that grow upright favor root development with good anchorage in the soil. Adequate seed coverage also insures good seed-soil contact, and reduces bird, rodent, and insect damage to germinating seed and developing seedlings. Poor seed-soil contact can be a problem with no-tillage systems (Harrold et al., 1970; Unger and Stewart, 1976).

Under moist soil conditions, the fluted coulter tends to press straw into the soil rather than cutting through it. This may interfere with good seed to soil contact and be detrimental to seed germination and emergence. This problem may be overcome by mounting a smooth or rippled coulter ahead of the row opener that will cut through the existing vegetation and crop residue and penetrate the soil to a uniform depth of 2 to 2 1/2 inches (Clapp, 1972; Hovermale et al., 1979). Sanford et al. (1973) stated that cutting through wheat stubble in case of dry conditions may prove difficult, but this problem may be overcome by adding some weight on the top of the planter.

The availability of equipment designed to perform the planting operation more satisfactorily, that is, cutting through the stubble of the previous crop remaining on the soil surface, and the development of new and improved herbicides to control grass and weeds, have increased the popularity of no-tillage systems.

Conventional Tillage

Kuipers (1963) stated the principle advantage of tillage is to get a good soil environment for plant growth. The relationship between the tillage operation and yield is affected by such factors as soil condition (soil type, pore space), the implements used in the operation, and the way in which the implements are used (working depth, speed).

Larson (1962) defined conventional tillage as a system of soil preparation for planting which includes plowing, disking, harrowing, and in many cases, subsequent cultivation. Conventional tillage uses a mold-board plow followed by liberal use of a disk, harrow, hoe, and cultivator. Conventional tillage is considered the standard of comparison for other systems (Sanford, 1982). Conventional tillage is the traditional system, which typically begins with a primary deep tillage operation followed by secondary tillage for seedbed preparation (Beaumer and Bakermans, 1973). The primary tillage at the beginning of a cropping or a fallow season usually improves soil structure (porosity and roughness), increasing water infiltration and the soil's resistance to wind erosion. Secondary (subsequent) tillage degrades soil structure and decreases protective cover, thereby reducing infiltration and increasing the soil's wind erodibility (Beaumer and Bakermans, 1973). Soane and Pidgeon (1975) reported that secondary tillage is required to prepare the top 10 cm of soil so that seed can be placed uniformly at the correct depth, insuring adequate soil-seed contact to provide water for germination and early growth, as well as eliminating large clods which can obstruct shoot and seedling roots.

Graffis et al. (1973) and Hoeft et al. (1975) stated the following advantages of conventional tillage: 1) results in uniformly fine seedbed for easy planting; 2) insecticides and herbicides may be incorporated as needed; 3) flexible and adaptable to a wide range of soil, crop, and weather conditions; 4) results in yields as high or higher than other systems over a wide range of soil and climatic conditions; and 5) necessary equipment is readily available on most farms.

Graffis et al. (1973) and Hoeft et al. (1975) also reported some disadvantages of conventional tillage include: 1) high cost because of the large number of operations; 2) often results in excessive tillage so that soil crusting and compaction may be a problem; 3) results in small aggregates (clods) so that water intake is reduced; 4) takes valuable time and decreases soil moisture in the plow layer, making it less suitable for double cropping; and 5) subjects fine and compact soil particles to wind and water erosion.

Graffis et al. (1973), Hoeft et al. (1975), Buntley (1977), Soane and Pidgeon (1975), and Kamprath et al. (1979) reported that the recompaction of the layer below the cultivated soil is due to the heavy traffic of implements used to conduct secondary tillage operations. This was largely offset by the loosening effect of primary tillage. Hard pans, caused by cementation processes, can also reduce root proliferation and penetration into horizons below the pan so that water uptake efficiency is decreased (Kamparth et al., 1979). The amount of soil damage occurring from wheel traffic is a complex and unknown variable. The proportion of the area of a field covered by tractor wheels during seedbed preparation by traditional tillage is approximately 90% for cereal crops but much higher for other crops, such as sugar beets. The amount of damage caused by tractor wheels would be reduced if the amount and distribution of wheel traffic could be restricted. Unger and Stewart (1976) proposed that reducing field operations or restricting field traffic to specific zones should maintain better soil conditions for planting and seedling establishment. Taylor (1967) stated that soil of sufficient density reduces root growth. However, a higher proportion of cultivation is generally necessary for root and vegetable crops having roots of large diameter, e.g., carrots and beets.

Another disadvantage of conventional tillage is the formation of a soil crust. Allen et al. (1975) and Sanford (1982) stated that intense rainfall of 8 cm occurred four days after planting time, and then a hot dry wind caused a dense crust formation on conventional till plots, preventing the emergence of soybean seedlings. In contrast, soybeans in no-tilled plots emerged to a near perfect stand. Still another disadvantage of continued tillage is reduction of emergence and survival of seedlings. Sanford (1982) reported that during land preparation by disking and harrowing, the loss of soil moisture through evaporation significantly reduced emergence and survival of seedlings.

Conventional tillage practices, which expose the bare soil during periods of potentially high runoff and evaporation serve to deplete the soil moisture supply or reduce the possibilities for moisture recharge when it is most needed (Unger and Phillips, 1973). Sanford (1982) reported that during land preparation by disking and harrowing, the loss of soil moisture through evaporation significantly reduced emergence and survival of seedlings.

Water Requirement

Plant water requirements change during the growing season. Water stress at some growth stages affects the crop yield more than at other stages (Stone et al., 1978). Greenland (1982) reported that drought caused complete crop failure for double cropped soybean and grain sorghum in eastern Oklahoma. Whenever rainfall is inadequate or not properly distributed through the growing season, supplementary irrigation usually increased the yield.

Brady et al. (1974), after a two-year study of irrigating soybean, found 1) irrigation increased the yield by 20%; 2) one-third to one-half of the total water requirement of the whole season produced equal yields if applied during the podding stage of plant growth; 3) most efficient use of water occurred when irrigation was initiated during the vegetative stages.

Soil water potential, in conjunction with atmospheric demand and plant factors, acts indirectly on growth through its influence on plant water potential, which in turn affects the rate of plant growth (Gandar and Tanner, 1976). According to Heatherly (1980), a plant's response to water is evidently more closely related to soil water potential than to any other single factor. As a result of his study (growth of soybean at different soil moisture potential), Heatherly (1980) found that for the most rapid vegetative growth and development of soybeans, soil moisture potential should be kept above -0.6 bars.

Finn and Brun (1980) reported that Co_2 assimilation and specific nodule activity decreased and stomatal resistance increased with increasing water stress. Bunce (1981) also stated that the photosynthetic rate of the soybean plant was decreased by water stress. Rathore et al. (1981) reported that moisture stress reduced leghemoglobin content of the root nodule and nitrogen uptake by plants. Water stress generally reduces the nodule number. Sionit and Kramer (1977) found that plants stressed during flower induction and flowering produce fewer flowers, pods, and seeds than controls because of a shortened flowering period and abortion of some flowers. Stress during early pod formation caused greatest reduction in number of pods and seeds at harvest. However, yield was reduced mostly by stress during early formation and pod stages.

Doss et al. (1974) stated that the pod-fill stage, from August 15 to September 20 for "Bragg" soybeans at Thorsby, Alabama, was the critical time for adequate water for maximum yield. Farah (1983) stated that yield reduction from water deficits depends not only on the magnitude of the deficit but also on the stage of the plant growth. Shipley and Regier (1970) found that withholding 10 cm irrigation during the six to eight leaf stage mid to late bloom stage, or heading and bloom stage, reduced yields 12, 35, and 45% respectively.

Eck and Musick (1979a) reported that when grain sorghum plants are stressed at the early boot stage and continued for 27 days or longer, the yields decreased as a result of reduction in number and size of seed, but when stress was initiated at heading or later, only seed size was decreased. Musick and Dusek (1971) reported that water stress influences yield primarily by reducing the size and/or number of heads (yield container), and limiting grain filling. Robins et al. (1967) reported that when sorghum was stressed during the boot to flowering stage, pollination failure (head blast) may occur, so grain yield is reduced. Moisture stress during the vegetative stage reduces the number and size of heads in grain sorghum. However, yield container (heading) can still be increased after heading by irrigation, stimulating tillers to develop heads and mature grain (Musick and Dusek, 1971). The most efficient use of one 10 cm seasonal irrigation resulted from applying water at heading or the milk stage of grain development.

Eck and Musick (1979b), after 2 years of studying plant water stress effects on nutrients in sorghum tissue, found that accumulation of all nutrients tended to be slowed by water stress. However, N and P are affected more than K, Ca, and Mg. Plant water stress decreased N concentration in leaves and increased it in stalk and heads. P concentration was decreased in leaves, but was affected in stalks and heads. Water use efficiency of sorghum is three times higher than soybeans. Teare et al. (1973) found that on a dry matter basis, water use efficiency for sorghum was approximately three times that of soybeans.

Weed Control

Erbach and Lovely (1974) reported that with continuous use of any tillage system, either conventional or conservation, weed control remains a concern, due to the fact that weed species can adapt to rotation of crops, tillage system, or weed control methods. An effective weed control system is necessary to prevent excessive crop losses. Kapusta (1979) noted that satisfactory weed control has been the major concern with minimum and no-till soybean production where mechanical cultivation is no longer possible. Muzik (1970) reported that the primary principle of weed control is to reduce weed competitiveness and thus prevent lower yield and/or quality. Undesirable weed competition may be reduced by altering the environment in order to produce conditions more favorable to crop production. An unfavorable environment may be modified with herbicides, tillage, crop rotation, or other crop production practices.

Jeffery et al. (1980) conducted an experiment on the effectiveness of certain herbicide combinations on weed control in double cropped no-tillage soybeans. They found that alachlor [2-chloro-2,6 diethyl-N-(methoxymethyl) acetanilide] + paraquat [1,1-dimethyl-4,4-bipyridinium] + surfactant, provided fair to good control of annual grass. Alachlor + Linuron 3(3,4-dichlorophenyl)-1-methoxyl-1-methylurea + paraquat + surfactant provided paraquat for contact kill of existing vegetation and linuron for preemergence and residual control of many broadleaf weeds. In most cases this treatment gave an excellent initial control of annual grass and broadleaf weeds.

Perennial weeds are difficult to control in most tillage systems. Glyphosate, within the herbicide combination of alachlor + Linuron + glyphosate [N-(phosphonomethyl) glycine] is effective against many perennial weeds, with potential for controlling both broadleaf and grassy perennial weeds. Chappel (1974) found that glyphosate being translocated controlled emerged perennial weeds more effectively than paraquat, and that both were effective in controlling emerged annual weeds.

In Oklahoma, where winter annual grassy weeds are a major problem in continuous wheat, paraquat and tillage combinations did not control weeds as well as moldboard plowing and cultivation (Davidson and Santelman, 1973).

Trifluralin (a,a,a-trifluoro-2,6 dinitro-N,N-dipropyl-

P-toluidine) is commonly used to control weeds in peas (Harvey and Gritton, 1977) and annual grass (Ndon et al., 1982). Trifluralin residues resulting from weed control in canning peas were observed to cause serious injury to double cropped grain sorghum and no injury to soybeans (Ndon et al., 1982). Burnside (1974) indicated that trifluralin residues persisted for one or more years, and Jacques and Harvey (1979) reported that trifluralin residues could be detected 75 to 100 days after application to peas. Trifluralin and nitalin are recommended in several states at the rate of 0.56 to 1.12 kg/ha (active ingredient) for control of annual weeds. However, effectiveness of herbicides depends greatly on species and stage of growth of the weed, and environmental conditions before, during, and after application (Carlson and Wax, 1968).

Johnsongrass (_Sorghum halenpense_ (L.) pers) is one of the most troublesome in many parts of the world. It is a very serious weed problem in the southeastern United States (McWhorter and Hartwing, 1965). Kincade (1971) effectively controlled most weed species in no-tillage planted soybeans with several herbicide combinations. He found that the johnsongrass population increased, and concluded that no-tillage soybeans should not be grown in a johnsongrass-infested field. Herbicides and cultivation only partially control johnsongrass, because the extensive rhizome system and seed remain viable for several years in the soil. Clapp (1972) proposed that in case of no-tilled soybeans, two kinds of herbicides are usually required: one to control existing vegetation (contact) and a second to control grass and weeds which may germinate after the soybean crop is planted (residual). A nonionic surfactant is also required to increase the effectiveness of the contact herbicides to control existing vegetation. Triplett (1978) used herbicides that have both foliar and residual activity to control weeds in double cropped soybeans planted with no-tillage methods.

Sanford et al. (1973) reported that regardless of the method of planting (conventional or no-tillage), cultivation is the best method of weed control where perennial weeds are a problem. Tillage helps control weeds by 1) killing emerging seedlings; 2) burying weed seeds and delaying growth of perennial weeds; 3) leaving rough surface to hinder weed seed germination; 4) providing enough loose soil at the surface to permit effective cultivation; 5) leaving a clean uniform surface for efficient action of herbicides; and 6) incorporating herbicides when necessary. Kincade (1971) obtained satisfactory weed control with cultivation and by direct spray of post-emergence herbicides, while Sanford et al. (1973) stated that linuron plus cultivation gave good control of all weeds. Reicosky et al. (1977) found that crop rotation, using the proper herbicide combinations, helped alleviate weed control problems. The greatest crop yield losses are caused by weed competition for light, nutrients, and water, rather than by difficulties during harvest (Burnside, 1973; Nave and Wax, 1971).

CHAPTER III

MATERIALS AND METHODS

A field study to determine the effects of irrigation and cropping systems on the yields of winter wheat, soybeans, and grain sorghum was conducted at the Vegetable Research Station near Bixby, Oklahoma in 1982 and 1983. Cropping systems used were monocrop-conventional tillage and double crop (after wheat grain removal) no-tillage. The experimental site was located on a Wynona silty clay loam. The Wynona series is classified as fine silty, mixed, thermic cumulic Haplaquolls. This series consists of deep slowly permeable, nearly level soil (0-1% slope) on broad flood plains.

The experimental design used for the wheat treatment yield analyses was a randomized complete-block design with five treatments and four replications. The wheat treatments consisted of monocropped rainfed wheat; double cropped wheat-soybeans where wheat was produced under rainfed conditions and soybeans were produced under both rainfed and irrigated conditions; and double cropped wheat-grain sorghum where wheat was produced under rainfed conditions and grain sorghum was produced under both rainfed and irrigated conditions. The yields of soybeans and grain sorghum were analyzed as a 2 X 2 factorial arrangement of treatments with the two factors and their respective levels being cropping systems (monocropped and double cropped) and irrigation (rainfed and irrigated) in a randomized complete-block design with four replications.

Conventional tillage (moldboard plowing + two tandom diskings) was used to prepare a seedbed for monocropped wheat. Double cropped wheat was planted directly into soybean stubble and after two tandom diskings of the grain sorghum stubble. All wheat plots were planted using a modified no-till hoe drill equipped with 50-cm smooth rolling coulters. 'TAM W-105' winter wheat was planted in the monocropped wheat plots on 1 Oct. 1981 and 4 Oct. 1982 at a rate of 54 kg/ha. The double cropped wheat plots were also planted with 'TAM W-105' on 4 Dec. 1981 and 20 Nov. 1982 at a seeding rate of 100 kg/ha. The wheat plots received a broadcast application of 135 kg N/ha as ammonium nitrate (NH_4NO_3) on 28 Feb. 1982 and 26 Feb. 1983, and was harvested on 28 June 1982 and 27 June 1983. Monocropped soybean and grain sorghum plots were winter fallowed, then plowed in the spring. Plots to be planted to grain sorghum received a broadcast application of 155 kg N/ha as NH_4NO_3 just before planting each year.

Trifluralin (a,a,a-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine) at 1.1 kg/ha active ingredient (a.i.) and propazine [2-chloro 4,b bis (isopropyl amino)-s-triazine] at 2.2 kg a.i./ha were applied to monocrop soybean (MCSB) plots and monocrop grain sorghum (MCGS) plots, respectively for weed control. Herbicides were incorporated with two tandem diskings prior to planting. Chemical weed control for the double cropped soybeans (DCSB) plots consisted of glyphosphate [N-(phosphonomethyl) glycine] at 1.1 kg a.i./ha and linuron [3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea] at 0.8 kg a.i./ha. Additional weed control measures used during the growing season included mechanical cultivation (monocrop only), hand hoeing and "wiping" with glyphosphate.

On 22 June 1982 and 17 June 1983, MCSB and MCGS were planted at a rate of 296,000 and 180,000 viable seed/ha, respectively, in 50 cm rows. Varieties used were "Forrest" (Maturity Group V) soybeans and "Paymaster BR-Y93" grain sorghum. Plot size was 19.8 X 9.14 m. Plots were planted with a no-till planter equipped with 5-cm fluted coulters, double-disk openers, 4-cm depth hands, and press wheels. DCSB and double cropped grain sorghum (DCGS) were planted into wheat stubble on 28 June 1982 and 29 June 1983 using the same varieties, rates, row spacings, and planter as for the monocrop plots.

Irrigated plots were sprinkler irrigated as required to avoid stress. Water was applied in quantities ranging from 5 to 7 cm per application. Total irrigation water applied is shown in Table I.

Grain yields were obtained by harvesting the center five rows of each plot with a Gleaner Model "A" combine. In 1982, the MCGS and DCGS plots were harvested on 19 Oct. The

MCSB and DCSB plots were harvested on 25 Oct. In 1983, the MCGS plots were harvested on 22 Sept.; the MCSB and DCSB on 16 Nov., and the DCGS on 17 Nov. All 1982 double cropped wheat plots had been double cropped in 1981 and all 1982 irrigated mono and double cropped soybean and grain sorghum plots had been irrigated in 1981.

TABLE I

IRRIGATION WATER APPLIED TO SOYBEANS AND GRAIN SORGHUM

Treatment	1982	1983
	--------cm-------	
MCSB	35	36
DCSB	35	36
MCGS	35	30
DCGS	35	36

CHAPTER IV

RESULTS AND DISCUSSION

Precipitation

In eastern Oklahoma, precipitation is generally adequate for crop growth during the late winter, spring, and early summer months. However, soil moisture is often limiting and critical for summer grown monocrops or for the second crop of a double cropping system, especially during late July and August. Monthly distribution and total rainfall amount from 1 Jan. 1982 to 31 Dec. 1983 and the 32-year monthly average (1952 to 1983) are given in Table II. Precipitation distributions within each month for 1982 and 1983 are given in Figures 1 and 2.

Wheat Yields

In general, the growing season for wheat in eastern Oklahoma extends from October to mid-June of the next year. Although precipitation amounts and distribution may have considerable year to year variation, irrigation of wheat is usually not practical for this region, and under the conditions of this experiment all wheat yields (monocropped and double cropped) were produced under rainfed conditions. Stand establishment of wheat was excellent for both years of

TABLE II

RAINFALL FROM 1 JAN. 1982 TO 31 DEC. 1983 AND THE 32-YEAR MONTHLY AVERAGE (1952-1983) AT THE VEGETABLE RESEARCH STATION NEAR BIXBY, OKLAHOMA

Month	1982	1983	32-yr Average
		cm	
January	9.1	6.5	4.0
February	1.2	7.1	4.0
March	2.0	4.8	6.5
April	3.1	8.5	9.6
May	19.9	17.7	12.7
June	15.6	6.9	11.9
July	5.9	2.6	8.4
August	5.8	0.7	6.7
September	2.0	4.1	10.0
October	4.2	26.0	8.5
November	15.9	7.8	6.9
December	8.1	1.3	4.4
TOTAL	92.8	94.0	93.6

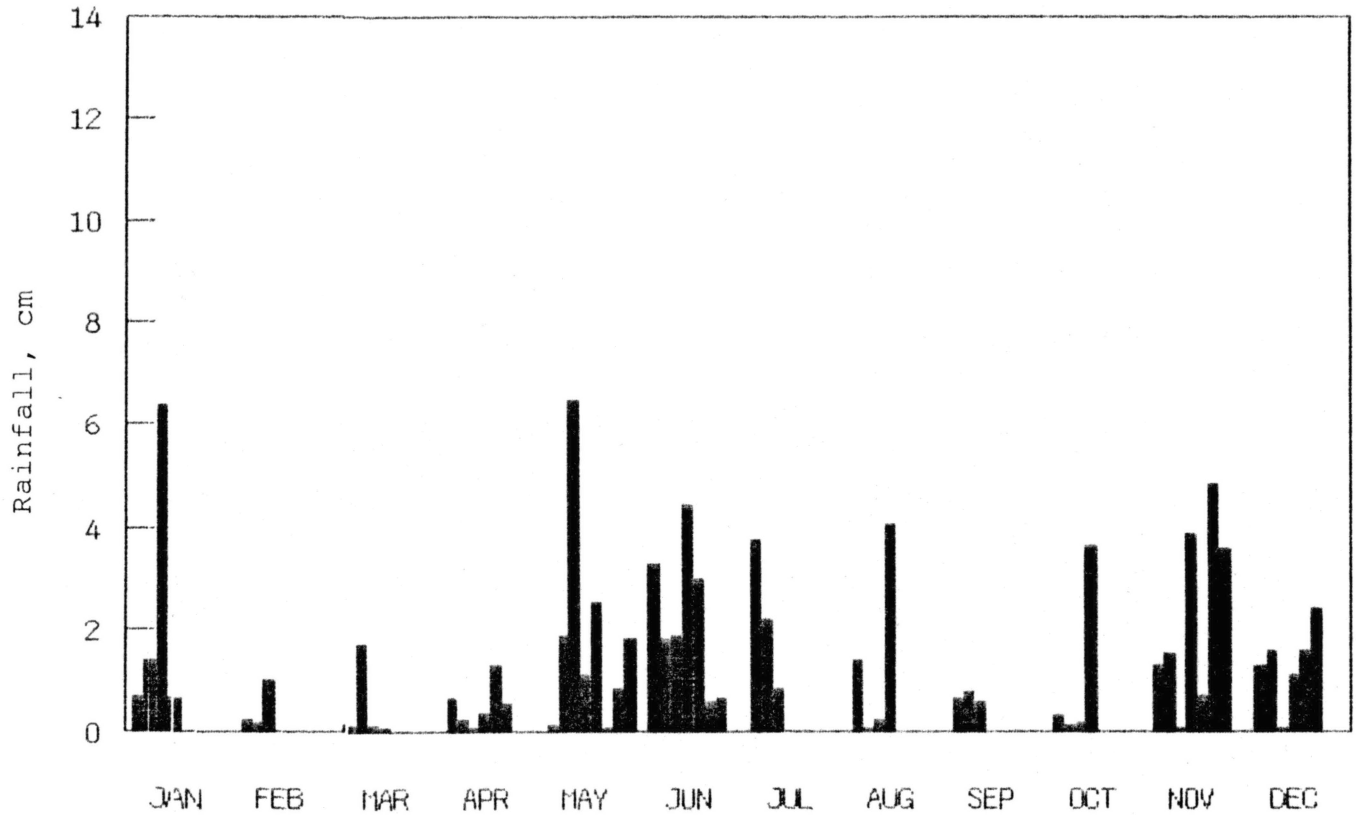

Figure 1. Rainfall Distribution During 1982

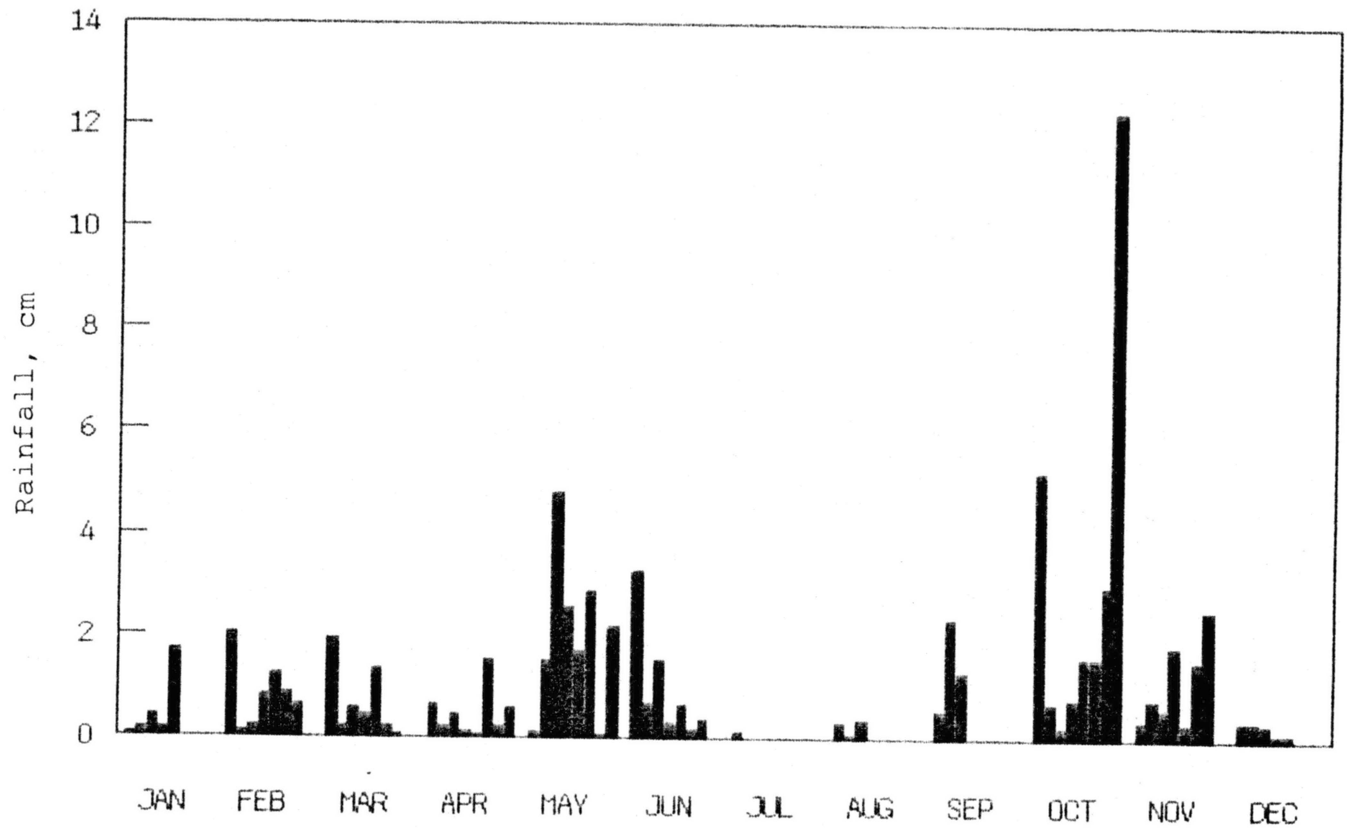

Figure 2. Rainfall Distribution During 1982

the study. However, vegetative growth and tillering lagged in 1982 compared to 1983 and can most likely be attributed to low rainfall in March and April (Figure 1).

The analysis of variance for the 1982 and 1983 wheat yields show a significant difference (0.01 level) between treatments (Table III). Treatments, yields, and least significant yield differences are given in Table IV. In 1983 the wheat yields for all cropping system treatments were higher than in 1982 (Table IV) and can be attributed to late winter and early spring rainfall amounts and distribution (Figures 1 and 2), and to cooler temperatures during the grain fill stage in May and June of 1983.

TABLE III

ANALYSIS OF VARIANCE FOR WHEAT YIELDS IN 1982 AND 1983

		1982		1983	
Source	df	MS	P. Value	MS	P. Value
Rep	3	115935		52748	
Treatment	4	277355**	0.0008	425503**	0.0001
Error	12	27521		14347	

**Significant at the 0.01 level

TABLE IV

WHEAT YIELD RESPONSES TO CROPPING SYSTEMS

Treatment	1982	1983	2-year Average
	----------kg/ha----------		
Monocropped wheat	2680a‡	3640a‡	3160
Wheat double cropped with IR+ soybeans	2020b	3220b	2620
Wheat double cropped with RF+ soybeans	2070b	3120b	2590
Wheat double cropped with IR+ grain sorghum	2240b	2820b	2530
Wheat double cropped with RF+ grain sorghum	2160b	2890b	2520
LSD (0.05)	256	185	

+IR - Irrigated; RF - Rainfed.

‡Means with the same letters within the same columns are not significantly different at the 0.05 level using the LSD test.

In both 1982 and 1983 monocropped wheat yields were significantly higher (0.05 level) compared to yields of the double cropped wheat (Table IV). This was anticipated because the monocropped wheat had an opportunity to make effective use of soil moisture that had been previously stored (during summer fallow) compared to the wheat double cropped with soybeans and/or grain sorghum. In 1982 there were no significant differences (0.05 level) between the double cropped wheat treatments (Table IV). However, in 1983 yields of wheat double cropped with soybeans were significantly higher than yields of wheat that were double cropped with grain sorghum (Table IV).

Similar results were reported by Crabtree and Makonnen (1981), and they attributed the decrease in yields to a grain sorghum residue phytotoxicity. This phytotoxicity effect appears to occur in years of increased rainfall (late February and early March), when the double cropped wheat following grain sorghum is in the one shoot stage of growth. The young wheat plants tend to exhibit leaf-yellowing and corkscrewing in the late winter and early spring. This stunting tends to carry over into the rest of the life cycle of the plant, resulting in decreased yields. Another possible explanation is that wheat double cropped with soybeans benefitted from nitrogen fixation by the soybeans.

Irrigation of the double crop, whether soybeans or grain sorghum, had no statistically significant effect on wheat yields of the following year within the same double cropping system (Table IV). This can be explained by the fact that in most years late fall, winter and early spring precipitation is adequate for recharging soil profile moisture.

When combined over the two year period (1982-83) the wheat yield data showed a significant (0.01 level) year effect (Table V). The analysis of variance for wheat yields with contrasts by individual year and combined over 1982-83 are given in Tables XII, XIII, and XIV (appendix), respectively. For each year and for the two years combined there was a significant (0.01 level) monocropped vs. double cropped effect.

TABLE V

ANALYSIS OF VARIANCE COMBINED OVER TWO YEARS (1982-83) FOR WHEAT YIELDS

Source	df	Mean Squares	P. Value
Rep	3	31396	0.5642
Treatment	4	581976**	0.0001
Error (a)	12	20461	
Year	1	8165918**	0.0001
Treatment X Year	4	120882	0.0701
Error (b)	15	44583	

**Significant at the 0.01 level.

Soybean Yields

The analyses of variance for soybean yields for 1982 and 1983 are given in Table VI. Significant treatment differences at the 0.01 level were obtained for both years. Monocropped irrigated soybeans yielded significantly higher (690 kg/ha) in 1983 compared to 1982 (Table VII). The magnitude in yield differences between 1982 and 1983 can in part be explained by the fact that in 1982 frost arrived unusually early (10 days) compared to the long term average first killing frost date. In 1982 monocropped irrigated soybeans yielded 2310 compared to 1820 kg/ha for the monocropped rainfed treatment. This difference was significant at the 0.05 level (Table VII). This response to irrigation was most likely due to the elimination of water stress during the pod fill stage of growth. Monocropped Forrest soybeans flower and set pods around 1 September, and from this time period to frost is critical for obtaining maximum yields. The rainfed monocropped soybeans received only 6.9 cm rainfall from 13 Aug. to 20 Oct. which includes most of the critical pod fill stage of growth.

TABLE VI

ANALYSIS OF VARIANCE FOR SOYBEAN YIELDS IN 1982 AND 1983

		1982		1983	
Source	df	MS	P. Value	MS	P. Value
Rep	3	7034		14555	
Treatment	3	379737**	0.0095	2653385**	0.0001
Error	9	53365		29309	

**Significant at the 0.01 level.

TABLE VII

SOYBEAN YIELD RESPONSE TO IRRIGATION AND CROPPING SYSTEMS

Treatment	1982	1983	2-year Average
	----------kg/ha----------		
Monocropped irrigated soybeans	2310a[‡]	3000a[‡]	2650
Monocropped rainfed soybeans	1820b	2610b	2220
Double cropped irrigated soybeans	1740b	2680b	2210
Double cropped rainfed soybeans	1590b	1170c	1380
LSD (0.05)	370	274	

[‡]Means with the same letters within the same columns are not significantly different at the 0.05 level using the LSD test.

In 1982 double cropped irrigated soybeans yielded 1740 compared to 1590 kg/ha for the rainfed double cropped soybean treatment (Table VII). There was no significant difference at the 0.05 level between these two treatments; this can possibly be explained by a difference in flowering (10 September) and length of time for pod filling. In both double cropping systems, the time for complete full season photosynthetic expression was cut short due to early frost, and a true measure of the benefits of irrigation for double cropped soybeans was not obtainable.

In 1983 monocropped irrigated soybeans yielded 3000 compared to 2610 kg/ha when monocropped under rainfed conditions (Table VII). The 390 kg/ha difference in yield magnitude can largely be attributed to poor rainfall amounts and distribution during July, August and early September (Figure 2). A similar rationale can be given for a difference in yields of 1510 kg/ha when double cropped soybeans were irrigated compared to the rainfed double cropped soybeans (Table VII). For the 1983 environment there was a significant (0.01 level) cropping system X irrigation interaction (Table XVI, appendix). When the soybean yield data were combined over the two year period, there was a significant (0.01 level) treatment, year, and treatment X year interaction effect (Table VIII). When averaged over the two year study period, the monocropped irrigated soybean treatment yielded 2650 compared to 2215 kg/ha for the rainfed monocropped treatment (Table VII). During these two years, the irrigated double cropped soybean treatment yielded am average of 2210 compared to 1380 kg/ha when grown under rainfed conditions.

Grain Sorghum Yields

The analyses of variance for grain sorghum yields are given in Table IX. Treatment, yield, and least significant yield differences are given in Table X. In 1982 no significant yield responses were obtained from irrigation for either monocropped or double cropped grain sorghum cropping systems (Table X). The contrast in rainfall distribution in July and August (Figures 1 and 2) for the

TABLE VIII

ANALYSIS OF VARIANCE COMBINED OVER TWO YEARS (1982-83) FOR SOYBEAN YIELDS

Source	df	Mean Squares	P. Value
Rep	3	14939	0.7465
Treatment	3	2256122**	0.0001
Error (a)	9	36697	
Year	1	2014527**	0.0001
Treatment X Year	3	777001**	0.0001
Error (b)	12	36145	

**Significant at the 0.01 level.

TABLE IX

ANALYSIS OF VARIANCE FOR GRAIN SORGHUM YIELDS IN 1982 AND 1983

		1982		1983	
Source	df	MS	P. Value	MS	P. Value
Rep	3	291454		71851	
Treatment	3	40878	0.9212	488375**	0.0001
Error	9	256930		78446	

**Significant at the 0.01 level.

TABLE X

GRAIN SORGHUM YIELD RESPONSE TO IRRIGATION AND CROPPING SYSTEMS

Treatment	1982	1983	2-year Average
	----------kg/ha----------		
Monocropped IR[+] grain sorghum	5910a[‡]	6160a[‡]	6040
Monocropped RF[+] grain sorghum	6090a	4990b	5540
Double cropped IR[+] grain sorghum	5960a	5330b	5640
Double cropped RF[+] grain sorghum	5860a	3510c	5680
LSD (0.05)	NS	448.0	

[+]IR - Irrigated; RF - Rainfed.

[‡]Means with the same letters within the same column are not significantly different at the 0.05 level using the LSD test.

two experimental years represents a classic example of how in some years growers can look forward to a significant yield response to irrigation, and other years little is gained from irrigation. In 1983 monocropped irrigated grain sorghum yielded 6160 compared to 4970 kg/ha for the rainfed grain sorghum treatment (Table X). Irrigated double cropped grain sorghum yielded 1820 kg/ha more than rainfed double cropped grain sorghum (Table X). This statistically significant (0.01 level) yield difference can be attributed to the dry conditions which resulted in only 5.4 cm of total rainfall in July, August and September of 1983. This lack of rainfall put a stress on the monocropped rainfed treatment during the boot, heading, and grain fill stages of growth. The double cropped rainfed treatment most likely had even a more severe water stress period during the same three stages of growth and resulted in a yield of 3510 compared to 5330 kg/ha for the irrigated double cropped grain sorghum (Table X). In 1983 there were significant irrigation and cropping system effects and a significant cropping X irrigation interaction (Table XVIII, Appendix).

When the data of two years were combined, the analysis of variance showed a significant treatment, year and treatment X year interaction (Table XI). For the two year duration of the experiment the irrigated monocropped grain sorghum yielded an average of 6040 compared to 5540 kg/ha for the rainfed monocropped grain sorghum. The irrigated double cropped grain sorghum yielded 5640 compared to 4685 kg/ha for the rainfed treatment for the same two year period (Table X).

TABLE XI

ANALYSIS OF VARIANCE COMBINED OVER TWO YEARS (1982-83) FOR GRAIN SORGHUM YIELDS

Source	df	Mean Squares	P. Value
Rep	3	213624	0.3445
Treatment	3	2584337**	0.0002
Error (a)	9	152012	0.5750
Year	1	7253018**	0.0001
Treatment X Year	3	234029**	0.0004
Error (b)	12	174944	

**Significant at the 0.01 level.

CHAPTER V

SUMMARY AND CONCLUSIONS

A field study (1982-83) was conducted at the Oklahoma State University Vegetable Research Station near Bixby, Oklahoma to evaluate the grain yields of mono and double cropped soybeans and grain sorghums grown under rainfed and irrigated conditions. Soybeans and grain sorghum were double cropped after wheat grain removal. All mono and double cropped wheat yields were produced under rainfed conditions.

Monocropped wheat yields were significantly higher than double cropped wheat yields in both years. There were no significant differences between the yields of double cropped wheat whether double cropped with soybeans or grain sorghum in 1982; however, wheat yields were significantly higher when double cropped with soybeans compared to grain sorghum in 1983.

Monocropped irrigated soybeans yielded 2310 and 3000 kg/ha compared to 1820 and 2610 kg/ha for rainfed monocropped soybeans in 1982 and 1983, respectively. No significant yield differeces were obtained from irrigation of double cropped soybeans in 1982; however, the irrigation of double cropped soybeans produced 2680 compared to 1170 kg/ha rainfed in 1983, and can be attributed to the seasonal differences in the amount and distribution of rainfall during the pod fill stage of growth.

In 1982 no significant yield responses were obtained from irrigation for either monocropped or double cropped grain sorghum. In 1983 monocropped irrigated grain sorghum yielded 6160 compared to 4970 kg/ha for the rainfed grain sorghum treatment. Irrigated double cropped grain sorghum yielded 5330 compared to 3510 kg/ha for rainfed grain sorghum.

When averaged over the two year period of this research project monocropped rainfed wheat yielded 3160 compared to 2565 kg/ha when double cropped under rainfed conditions with soybeans and/or grain sorghum. Monocropped irrigated soybeans yielded 2650 compared to 2220 kg/ha for the monocropped rainfed soybeans. Double cropped irrigated soybeans yielded 2210 compared to 1380 kg/ha for the double cropped rainfed soybeans. Monocropped irrigated grain sorghum yielded 6040 compared to 5540 kg/ha for the rainfed monocropped grain sorghum. Double cropped irrigated grain sorghum yielded 5640 compared to 5680 for the double cropped rainfed grain sorghum. There was a significant (0.01 level) year effect on the yield response to irrigation for soybeans and grain sorghum.

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TABLE XII

ANALYSIS OF VARIANCE OF WHEAT YIELDS WITH CONTRASTS FOR 1982

Source	df	Mean Squares	P. Value
Total	19		
Rep	3	115935	0.0298
Treatment	4	277355**	0.0008
MC vs. DC	1	1000470**	0.0001
Sb vs. Gs	1	92313	0.0920
Rf vs. Ir	1	1387	0.8261
Grain vs. Water	1	15250	0.4710
Error	12	27521	

**Significant at 0.01 level.

MC = monocrop, DC = double crop
Sb = soybean, Gs = grain sorghum
Rf = rainfed, Ir = irrigated
Grain = soybean or grain sorghum
Water = rainfed or irrigated

TABLE XIII

ANALYSIS OF VARIANCE OF WHEAT YIELDS WITH CONTRASTS FOR 1983

Source	df	Mean Squares	P. Value
Total	19		
Rep	3	71851	0.0436
Treatment	4	488375**	0.0001
MC vs. DC	1	1280812**	0.0001
Sb vs. Gs	1	391007	0.0002
Rf vs. Ir	1	1110	0.7856
Grain vs. Water	1	29083	0.1800
Error	12	78446	

**Significant at 0.01 level.

MC = monocrop, DC = double crop
Sb = soybean, Gs = grain sorghum
Rf = rainfed, Ir = irrigated
Grain = soybean or grain sorghum
Water = rainfed or irrigated

TABLE XIV

ANALYSIS OF VARIANCE OF WHEAT YIELDS OVER YEARS (1982-83) WITH CONTRASTS AND INTERACTIONS

Source	df	Mean Squares	P. Value
Total	39		
Rep	3	31396	0.5642
Treatment	4	581976**	0.0001
MC vs. DC	1	2272638**	0.0001
Sb vs. Gs	1	51672	0.2987
Rf vs. Ir	1	2489	0.8164
Grain vs. Water	1	1106	0.8769
Rep X Treatment	12	2046	0.9099
Year	1	8165918**	0.0001
Treatment X Year	4	120882	0.0701
Error	12	44583	

**Significant at 0.01 level.

MC = monocrop, DC = double crop
Sb = soybean, Gs = grain sorghum
Rf = rainfed, Ir = irrigated
Grain = soybean or grain sorghum
Water = rainfed or irrigated

TABLE XV

ANALYSIS OF VARIANCE OF SOYBEAN YIELDS WITH 2 BY 2 FACTORIAL ARRANGEMENT FOR 1982

Source	df	Mean Square	P. Value
Total	15		
Rep	3	7034	0.9387
Treatment	3	379737**	0.0095
Irrigation	1	398395*	0.0231
Cropping System	1	627142**	0.0075
Irr. X Crop. System	1	113673	0.1784
Error	9	53365	

**Significant at the 0.01 level.

*Significant at the 0.05 level.

TABLE XVI

ANALYSIS OF VARIANCE OF SOYBEAN YIELDS WITH 2 BY 2 FACTORIAL ARRANGEMENT FOR 1983

Source	df	Mean Square	P. Value
Total	15		
Rep	3	14555	0.9387
Treatment	3	2653385**	0.0001
Irrigation	1	3585563**	0.0001
Cropping System	1	3126196**	0.0001
Irr. X Crop. System	1	1248397**	0.0001
Error	9	29309	

**Significant at the 0.01 level.

TABLE XVII

ANALYSIS OF VARIANCE OF GRAIN SORGHUM YIELDS WITH 2 BY 2 FACTORIAL ARRANGEMENT FOR 1982

Source	df	Mean Square	P. Value
Total	15		
Rep	3	291454	0.3862
Treatment	3	40878	0.9212
Irrigation	1	6778	0.8746
Cropping System	1	33951	0.7246
Irr. X Crop. System	1	81904	0.5861
Error	9	256930	

TABLE XVIII

ANALYSIS OF VARIANCE OF GRAIN SORGHUM YIELDS WITH 2 BY 2 FACTORIAL ARRANGEMENT FOR 1983

Source	df	Mean Square	P. Value
Total	15		
Rep	3	71851	0.4713
Treatment	3	488375**	0.0001
Irrigation	1	8889178**	0.0001
Cropping System	1	5341101**	0.0001
Irr. X Crop. System	1	420977**	0.0001
Error	9	78446	

**Significant at the 0.01 level.

VITA

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