Reduced Tillage Effects on Irrigation Management in Cotton

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Abstract

Conservation or reduced tillage practices in cotton-based crop rotation systems were studied in field experiments initiated at Marana, Coolidge and Goodyear in 2001. Following barley cover and grain crops, soil and water management assessments were made during the 2002 cotton season at the three sites. Cover and grain crop residues and a lack of tillage prior to planting cotton or during the cotton season increased the infiltration of irrigation water into coarse-textured soils, slowed irrigation advance times, and increased the amount of irrigation water used at two of the three sites compared to conventional tillage treatments.

Introduction

Conventional cotton production practices in Arizona typically involve several tillage operations, including land-planing, leveling, several disking operations, chisel plowing, and cultivation for weed control and maintenance of irrigation furrows. Arizona statutes related to pink bollworm (*Pectinophora gossipiella*, Sanders) control require some tillage following cotton harvest, although recent regulatory changes have allowed a reduction in tillage. Tillage operations may lead to degradation of soil structure, oxidation of organic matter and soil loss through wind and water erosion.

Conservation tillage is an alternative production system that offers numerous economic and environmental benefits. Over time, crop residue on the soil surface may increase the infiltration of water into the soil by 25-50% relative to conventional tillage production, reduce crusting and decrease the effect of wind and temperature on soil water evaporation from the soil surface (Baumhardt and Lascano, 1999; Daniel et al., 1999). Reducing tillage operations can also enhance cotton root growth by minimizing soil compaction. Raper et al. (1998) reported that the greatest cotton root growth, greatest depth to hardpan, and least amount of compaction occurred in a wheat–cotton double-crop study when subsoiling was done in combination with no-till planting into the grain stubble and no follow-up tillage operations were done during the cotton season.

These beneficial effects of conservation tillage practices related to soil and water management can enhance environmental quality and improve the natural resource base on which a large portion of Arizona's agricultural economy depends. A cotton-centered conservation tillage project was started in the fall of 2001 with the planting of oat and barley cover crops and barley grain crops. The objective of the soil and water management component of this project was to evaluate the effects of the conservation tillage on irrigation management over at least a 3-year period.

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Materials and Methods

Soil and water management assessments were made in conservation tillage field experiments already established on two commercial farms (Coolidge and Goodyear) and at the University of Arizona's Marana Agricultural Center. Treatments varied among the experimental sites. At Fast Track Farms (cooperator: Greg Wuertz, Coolidge, AZ), the tillage/cover crop treatments were: (1) conventional tillage/winter fallow followed by conventional cotton; (2) minimum tillage/oat cover crop, followed by no-till cotton planting; and (3) minimum tillage/Solum barley cover crop followed by no-till cotton planting. For this analysis, only treatment 1 (conventional) and treatment 3 (conservation) were measured in 2002.

Treatments at A Tumbling T Ranch (cooperator: Ron Rayner, Goodyear, AZ) were: (1) fall no-till/Poco barley grain crop, spring no-till cotton planting; (2) fall minimum tillage/Poco barley grain crop, spring no-till cotton planting; and (3) fall minimum tillage/Poco barley grain crop, spring minimum tillage cotton planting. Fall minimum tillage consists of two disking operations prior to planting barley and spring minimum tillage also consisted of two disking operations. Again, only treatment 1 (conservation) and treatment 3 (conventional) were measured at the Goodyear site in 2002.

Treatments at the Marana Agricultural Center were: (1) conventional tillage/winter fallow, conventional cotton planting in April (early planting); (2) conventional tillage/winter fallow, conventional cotton planting in late May/early June (late planting); (3) minimum tillage/no-till barley cover crop, no-till early cotton planting (there were three subplots: one brittle stem barley subplot and two Solum barley subplots); and (4) minimum tillage/no-till Solum barley grain crop, no-till late cotton planting. Treatment 1 (conventional) and treatment 3 (conservation) were analyzed at the Marana site in 2002.

The impact of conservation tillage on irrigation practices was assessed by analyzing infiltration and irrigation water advance times. At Coolidge and Marana, where crops were planted on beds and furrow-irrigated, blocked furrow infiltrometers similar to those reported by Walker and Skogerboe (1987) were used. These infiltrometers consisted of two pieces of stainless steel metal cut to the geometry of a furrow. The metal was pounded into the soil one meter apart. The furrows on either side of the furrow being measured were also blocked off (using soil dams) and irrigated at the same time, as was the measured furrow outside of the metal sheets. This was done to minimize horizontal water movement and simulate measurements being taken during an actual irrigation event. Water was then emptied into the dam created by the two pieces of metal and the height measured. As the water infiltrated into the soil, more water was added. Water height measurements were taken every 30 seconds for the first 2 minutes, then every minute for the next three minutes. Then, measurements were taken every 5 minutes until 1 hour had past. Measurements were then taken every ten minutes, then every 20 minutes and then every 30 minutes for the next three hours and were terminated after 4 hours. As the water was added, the time and amount was noted. At the end of the measurement period when all the water had infiltrated into the soil, the furrow geometry was measured and infiltration was determined. Throughout the entire measurement periods, the water level in the area surrounding the measurement zone was kept constant.

At Goodyear, where crops were planted in level basins and flood-irrigated, a modified ring infiltrometer similar to that described by Haise *et al*. (1956) was used. The inner ring was a piece of well casing 12 inches in diameter, and the outer ring was constructed from soil. Again, the outer ring, acting as a mote, was filled with water and was maintained at a level to simulate an irrigation event. The inner ring was filled with water, measurements were recorded and water was added when needed as described above.

The advance times and field slopes were measured a few days after infiltration data were collected at the three sites. For the Marana and Coolidge sites, measurements were made in three conventional and three conservation tillage plots of the early cotton planting treatments. At the Goodyear site, measurements were made in only one plot of the spring no-till and spring minimum tillage treatments. This was due to the irrigation timing (occurring at night) and the change in the irrigation set times during the irrigation event. Field slopes were determined in the plots where the infiltration and advance time data was collected. The slope was measured by setting up a survey transit in the center of the plot and then measuring 400 ft up and 400 ft down the furrow. These measurements gave a rough estimate of the overall slope of the field and helped to explain the advance times. In addition to the soil water parameters measured, the soil texture at each site was characterized. Soil samples were taken every six inches down to a depth of 2.5 ft and the percent sand, silt and clay was measured using the hydrometer or Bouyoucos method (Bouyoucos, 1936).

Results and Discussion

Soil Texture

The Coolidge site contained the greatest amount of sand of the three surface irrigated sites (Figure 1). Although there was some variation between depths at Coolidge, overall, the percentages of the particle size categories stayed fairly constant with clay slightly increasing with depth while sand slightly decreased. Overall, the soil was classified as a sandy clay loam. With clay contents above 40% in the top two ft of the soil profile, the soil at the Marana site contained the greatest percentage of clay among the experimental sites (Figure 1). The sand and silt contents varied slightly with depth and there was a relatively large change at the 2-ft depth. Soil classifications for each layer ranged from clay to sandy clay but overall the soil at Marana was classified as clay soil. The Goodyear site had greater than 50% silt throughout the upper 2.5 ft of the soil profile (Figure 1). The clay content was greater in the top two feet and then decreased to almost equal the percentage of sand at the 2.5-ft depth. The soil types ranged from silty clay loam to silty clay to silt loam, but overall, the Goodyear soil was classified as a silty clay loam. Crusting of the soil did not appear to be a problem at any of the sites based on cotton emergence and stand establishment (Adu-Tutu *et al*., 2003), and fertility management was similar in both the conventional and minimum tillage treatments.

Infiltration

Minimum tillage practices were expected to increase infiltration by leaving old root channels and soil cracks intact, allowing the water to flow deeper through the soil vadose. Also, surface organic residues usually slow the advance of the water front resulting in increased opportunity time for infiltration. However, in some surface irrigation situations, increased infiltration may actually hinder the movement of water down the field, resulting in excessive water use and reducing irrigation efficiency. Infiltration measurements were performed at the Coolidge site on 22 May 2002. Due to the large sand content in the soil at this site (Figure 1), the infiltration was relatively high with 10 and 7 inches of water infiltrating the soil in a 4-hr period in the reduced and conventional tillage treatments, respectively (Figure 2). The Marana site contained a much higher concentration of clay than the Coolidge site. Infiltration measurements were done on 4 and 5 June 2002. Both conventional and reduced tillage systems infiltrated an average of 4 inches of water in a 4-hr measurement period with the soil almost reaching full saturation (Figure 3). The Goodyear site was silty, and the soil was relatively moist at the time of assessment. Infiltration data was recorded on 20 and 21 June 2002. Within the 4-hr infiltration measurement period, an average of 1.5 inches of water infiltrated the reduced tillage treatment while 1 inch of water infiltrated the conventional tillage treatment, with both tillage systems approaching steady state (Figure 4). These results indicate that on coarse textured soils, conservation tillage practices did appear to increase infiltration as expected. In the finer textured soil at Marana, there was initially a slightly faster infiltration rate but little difference over most of the 4-hr measurement period.

Advance Times and Field Slope

The Coolidge site had a fairly shallow field slope of 0.06%. Advance time measurements (3-5 June 2002) showed that the irrigation water reached the end of the conventional plots in about one hour but had not reach the end of the conservation tillage plot after 8.5 hr, at which point measurements were suspended due to darkness (Figure 5). Both wheel and non-wheel furrows were to be measured but due to breaks in the beds where the water would cross over into the adjoining furrow, only wheel rows were measured. The grower’s set times for irrigating the conventional and conservation tillage plots were 6 and 12 hrs, respectively. The Marana field had a slightly greater slope of 0.08%. The advance times recorded on 6 June 2002, for both wheel and non-wheel rows are shown in Figure 6. Irrigation water advanced faster down the wheel rows in both treatments compared to the non-wheel furrows. Surprisingly, irrigation water advanced faster in the conservation tillage non-wheel furrow than in the conventional non-wheel furrow. The reason for this is not known at this time. The Goodyear site with a field slope of 0.12% had the greatest measured slope of the three sites. Advance times measured on 22 June 2002 in two treatments in the level basins are shown in Figure 7. At the beginning of the irrigation, water seemed to be advancing at the same rate in both treatments. However, by the end of the measurement period, the advance times differed by about 1 hr. Measurements were suspended at 1000 ft from the ditch because water was backing up within the plot, making it impossible to determine advance times beyond that point. In fact, for the conventional plots, in-field borders, running perpendicular to the water flow were constructed along both sides of the basins to slow water advancement and to help evenly distribute the water.

Irrigation Water Applied

Conservation tillage plots received more water (76.5 acre-in at Coolidge and 39.38 acre-in at Marana) than the conventional plots (55.5 acre-in at Coolidge and 37.19 acre-in at Marana) in the same field. At Goodyear, both tillage systems received the same amount of water (67.4 acre-in). Thus, as expected, reduced or conservation tillage practices increased irrigation advance times and the amount of water applied to the cotton crop at Coolidge and Marana. However, the greater field slope at Goodyear appeared to have minimized the effect of tillage practices on irrigation advance times and the amount of water applied. At Coolidge, the low slope and low flow rate on a sandy soil led to excessive water use. The long set time meant inefficient irrigation, causing an additional 21 in of water to be applied. At Marana, a high clay content and additional surface trash on the conservation tillage plots did not impact irrigation management, and flow rate did not differ among the tillage systems. At Goodyear, the presence of surface trash on the no-till plots helped to slow down the water front, an effect similar to the construction of in-field borders on the reduced tillage plots.

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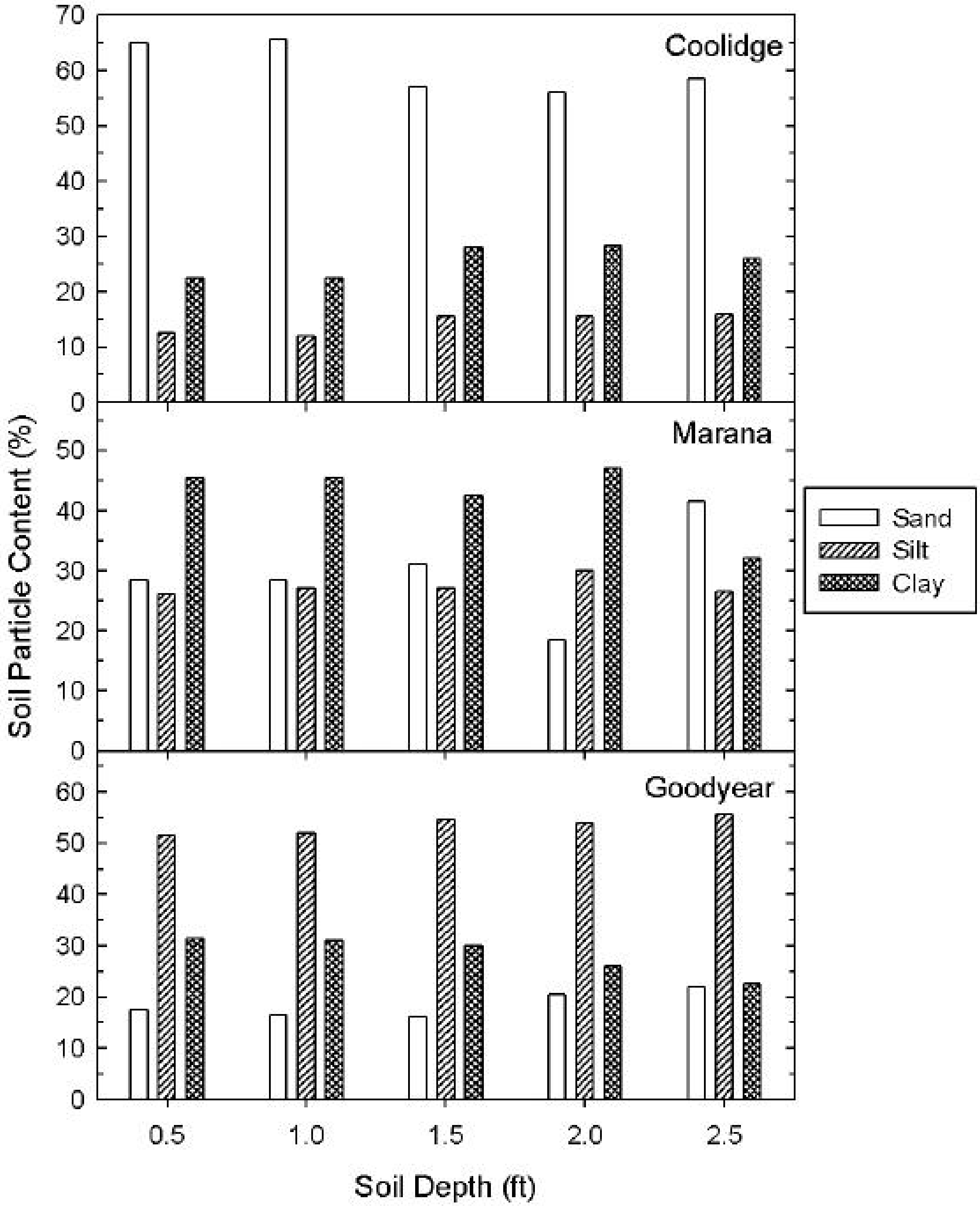

Figure 1. The average sand, silt and clay content at depths of 0.5 to 2.5 ft in the sandy clay loam soil at Coolidge, in the clay soil at Marana, and in the silty clay loam soil at Goodyear.

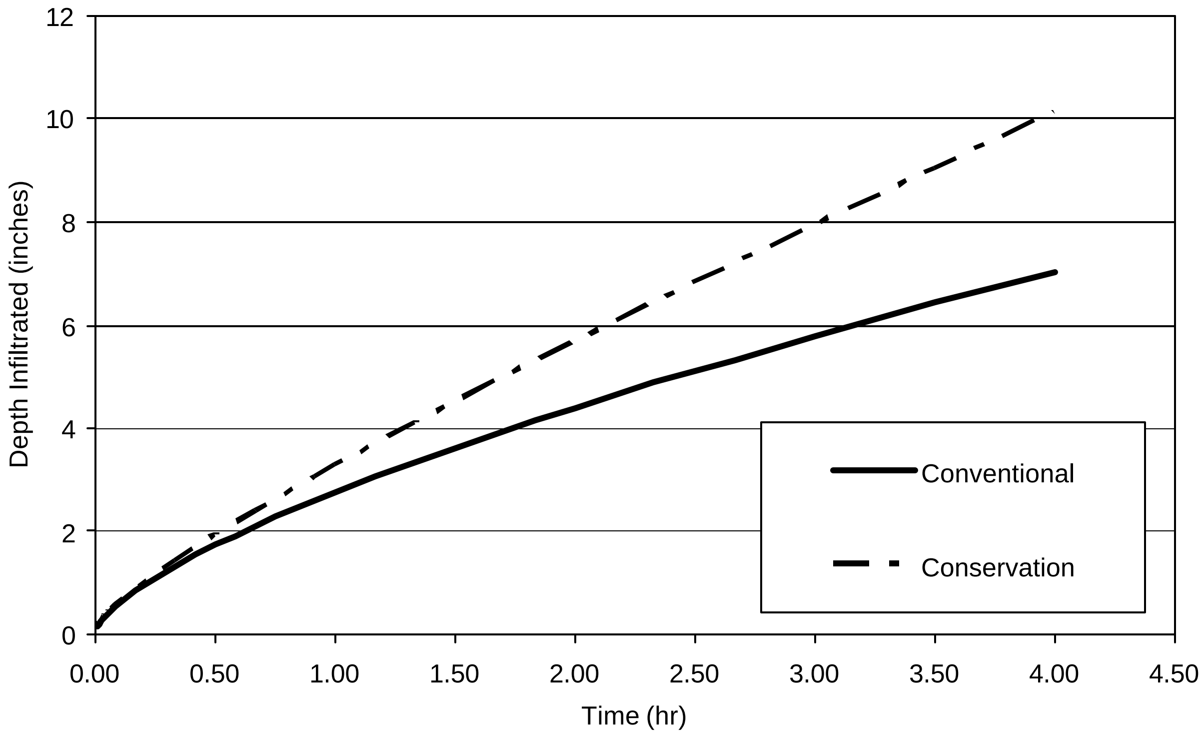

Figure 2. A comparison of the average depth of water infiltrated in the conventional and conservation tillage treatments at Coolidge in May 2002.

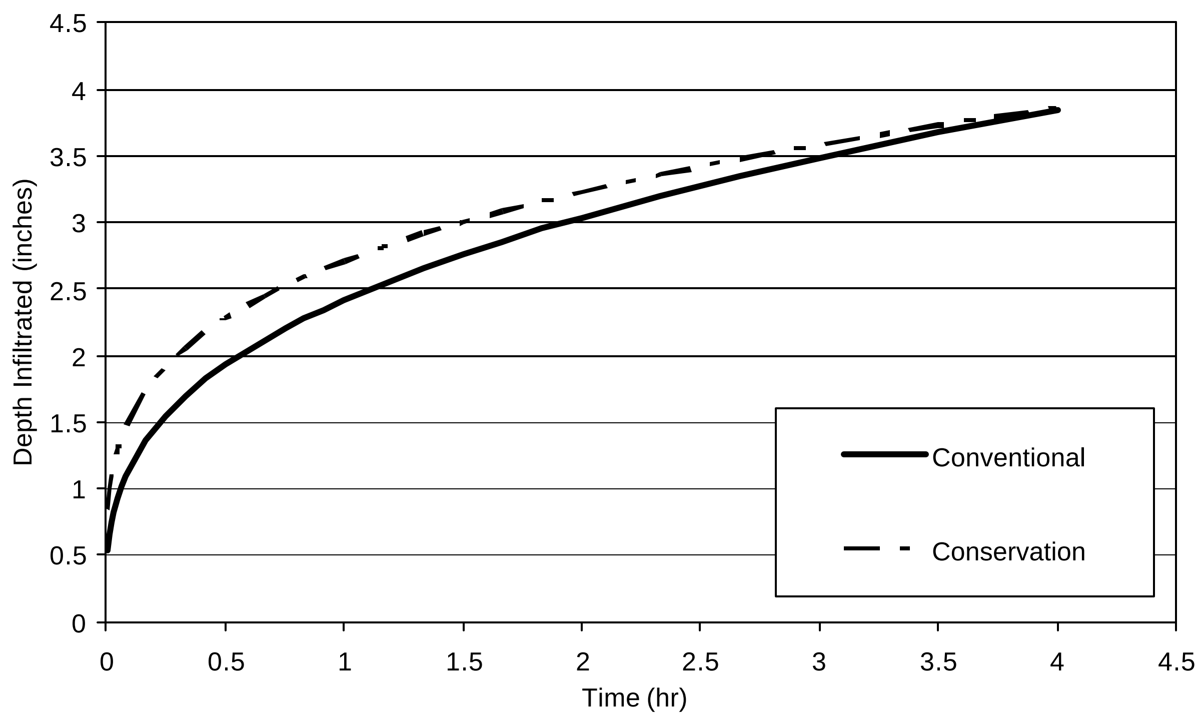

Figure 3. A comparison of the average depth of water infiltrated in the conventional and conservation tillage, early cotton planting treatments at Marana in June 2002.

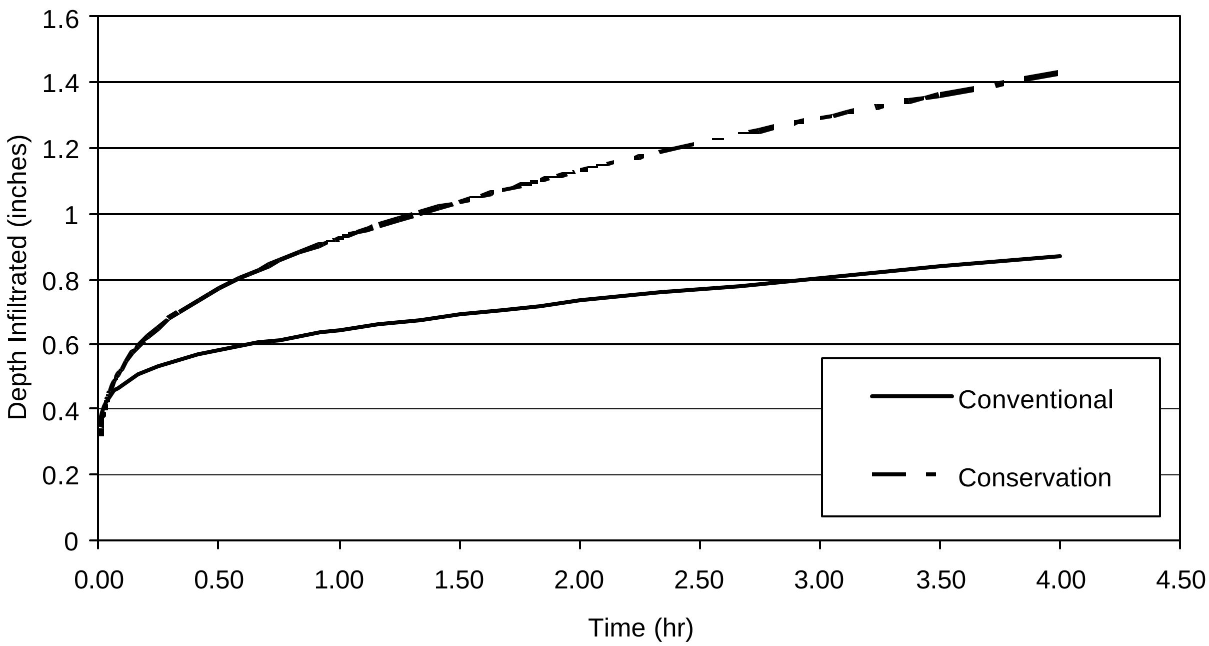

Figure 4. A comparison of the average depth of water infiltrated in the conventional and conservation tillage treatments at Goodyear in June 2002.

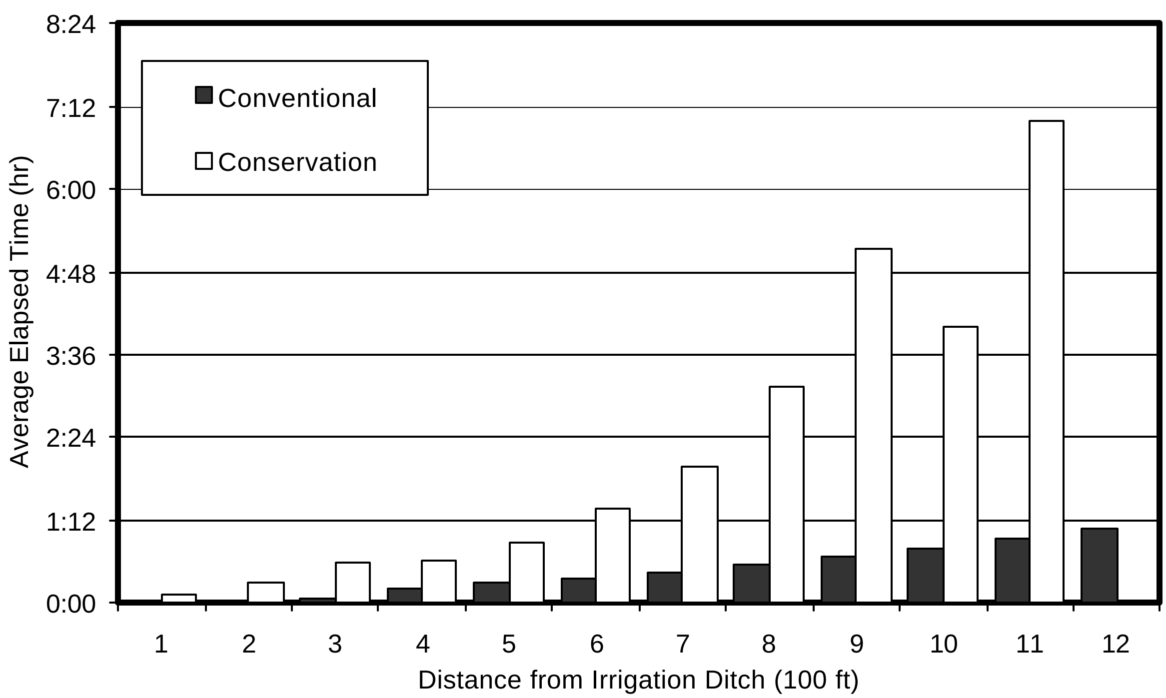

Figure 5. Average irrigation advance times in the conventional and conservation tillage treatments at Coolidge in May 2002.

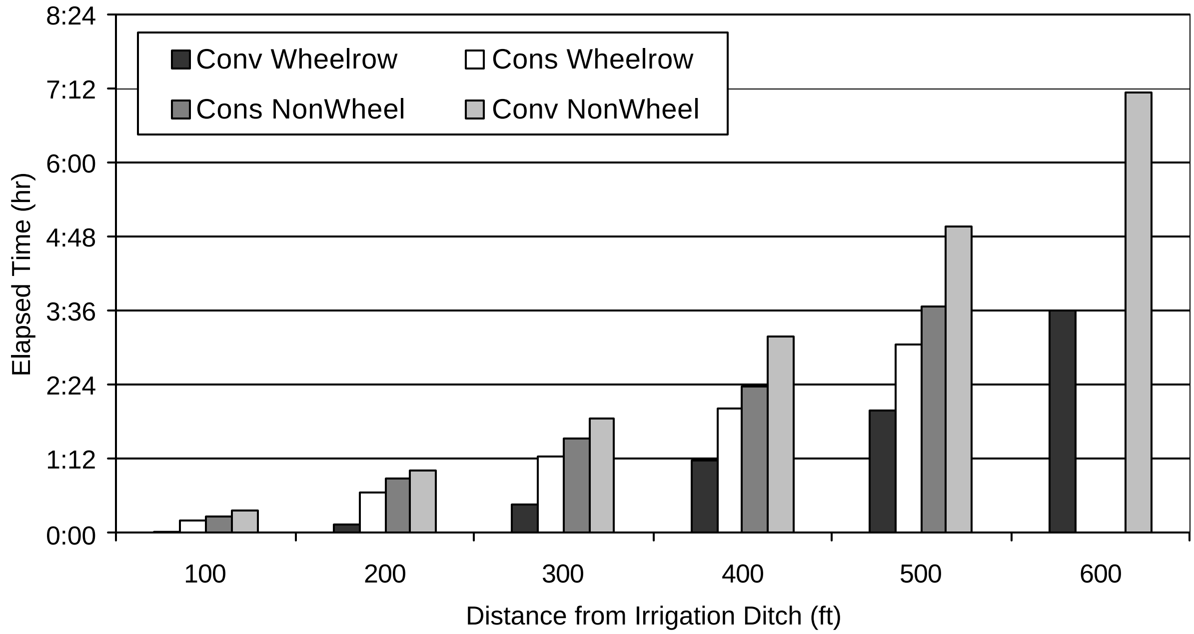

Figure 6. Average irrigation advance times measured in wheel and non-wheel furrows in the conventional (Conv) and conservation (Cons) tillage treatments at Marana in June 2002.

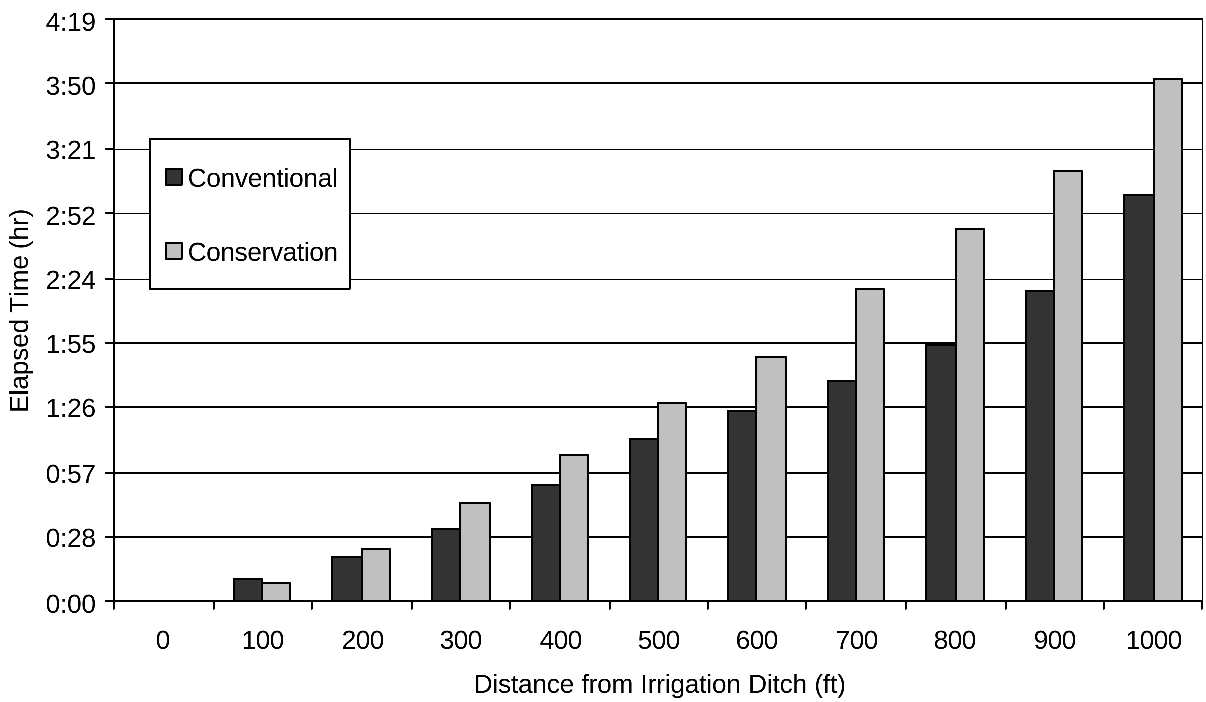

Figure 7. Average irrigation advance times in the conventional and conservation tillage treatments at Goodyear in June 2002.