Deficit Irrigation of Runner Peanut in the Texas Southern High Plains: Five Years of Research

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ABSTRACT

Responses of peanuts to irrigation application methods and quantity were measured in large field experiments conducted during the 1995 through 1999 crop years. Irrigation was by a center-pivot system with drop nozzles on a circular planting pattern. All irrigation applications prior to 60-70 days after planting (DAP) were equal and in the Low Elevation Spray Application (LESA) mode. Application of different irrigation quantities and methods began at 60-70 DAP and continued until early- to mid-September. Irrigation frequency was 2.5 or 3.5 days during the experimental period in each crop year. Irrigation levels were those needed to replace 1.25, 1.00, 0.75, 0.50, and 0.25 times calculated cotton evapotranspiration (ET) in 1995 and 1996; 1.00, 0.75, and 0.50 ET in 1997; 0.75 and 0.50 ET in 1998; and 0.75 ET in 1999. Application methods compared were Low Energy Precision Application (LEPA) mode (using drag socks) in alternate furrows (LEPA-AF), LEPA mode in every furrow (LEPA-EF), and LESA mode in alternate furrows. Yields have varied from less than 2,000 to more than 6,000 kg/ha, depending on irrigation treatment and crop year. In 1999, 0.75 ET levels were applied as LEPA-AF, LEPA-EF, and LESA on single row (SR), double row (DR), and ultra narrow row (UNR) planting patterns. Conclusions: (1) High-frequency, LEPA-AF application of irrigation water (using drag tubes) supplied adequate water and maintained adequate pod-zone moisture during the July-mid Sept period with circular-row planting on a relatively level field site with sandy loam soil. (2) Calculated cotton ET served as a reliable guide for irrigation water quantities. (3) During most crop years, 75% ET replacement during the pod development period appears to be adequate, if the soil profile is full at the beginning of that period of time. (4) LEPA-AF tended to come closer to fulfilling plant needs when water application rates were inadequate--50% and 25% ET replacement as compared to LESA. Alternate-furrow irrigation reduces the wetted soil area and, therefore, reduces evaporation losses. (5) LEPA-AF did not work as well on UNR or DR as on SR in 1999, indicating that the narrow pod development zone found in West Texas, relative to traditional growing regions, is involved in the success experienced with LEPA-AF.

INTRODUCTION

Peanut production in the northwestern quarter of Texas has increased greatly since the late 1970's and early 1980's. Because of the low rainfall in the Texas Southern High Plains (THSP counties are shown in Figure 1), irrigation management is important to produce acceptable yields of high quality peanuts, to balance the cost of irrigation with its benefits, to produce a good fit of peanut production within the overall farm enterprise, and to conserve the water resource.

Irrigation efficiency and labor requirements were greatly improved with the development of center-pivot irrigation systems with dropped-nozzles and reduced water pressure requirements. By not spraying water up into the atmosphere, as with traditional impact sprinklers, evaporative loss into the dry air was reduced and irrigation efficiency increased. Different water application patterns are possible with the reduced-pressure dropped-nozzles. Low Energy Precision Application (LEPA) irrigation is a system that combines (1) water application directly to the soil with drag tubes; (2) a planting pattern that matches the motion of the irrigation system (circular rows for center pivots; straight rows for lateral-move systems); (3) application directly into alternate furrows; (4) diking within the watered furrow to keep water where it is delivered without excessive runoff; and (5) relatively high frequency of water application, typically every 2.5 to 5 days. Dr. Lyle advocates using an irrigation interval that includes a half-day so that the same portion of the field is not always watered during the same time of the day. Infiltration rates of the soil influences irrigation frequency, because too much water at an application will cause washing out of the furrow-dikes or beds. Low Elevation Spray Application (LESA) uses spray applicators to deliver water near the top of the crop canopy in a manner in which water from each nozzle usually overlaps with swaths from adjacent nozzles. LESA typically uses lower frequency of irrigation cycles (5 to 7 days) with more water applied with each cycle. Although the term LEPA is frequently used to describe any irrigation technique using center-pivots and reduced- pressure dropped-nozzles, most West Texas peanut fields are actually watered by LESA with straight rows under a center-pivot irrigation system using some sort of spray application heads. See Figure 2 for definitions of irrigation terms.

Because irrigation water supply and rainfall are generally inadequate to replace all of the water lost by the crop during significant portions of the growing season, irrigation usually replaces only a part of water loss (deficit irrigation). Water loss is called evapotranspiration (ET) and includes that lost by evaporation (from the soil and other surfaces) and that removed by transpiration (through the plants). The challenge is to determine what portion of the water loss to replace throughout the season and how. Daily ET losses can be estimated using potential evapotranspiration (PET) values calculated from daily climatic conditions and crop coefficients specific to crop species and crop growth stages. Although crop coefficients have been published for the peanut, these were devised under vastly different conditions than those of the TSHP. Because of this and the fact that we are growing peanuts in a cotton-based system, we chose to use Cotton ET to approximate Peanut ET.

This research was conducted during the 1995, 1996, 1997, 1998, and 1999 crop years. The research site is the Agricultural Complex for Advanced Research and Extension Systems (AG-CARES) at Lamesa, Texas. AG-CARES is a cooperative effort of Lamesa Cotton Growers, Texas Agricultural Experiment Station, and Texas Agricultural Extension Service. The AG-CARES project, which began in 1990, emphasizes “concepts of precision agriculture, conservation tillage, wind protection, LEPA irrigation, and environmentally sound practices which will support profitable and sustainable agricultural systems for the area.” The land and crop production costs are furnished by the Lamesa Cotton Growers, with additional support for peanut production expenses from the Western Peanut Growers Association. This research was partially funded by the Texas Peanut Producers Board and the Precision Agricultural Initiative for the Texas High Plains. The site, industry support, and cooperating scientists involved offered a unique opportunity to study irrigation management as well as other peanut production topics.

This article summarizes five years' research designed to determine (1) the response of runner peanuts to different quantities of water based on replacement of calculated Cotton ET and (2) the response of runner peanuts to different irrigation application methods in the TSHP (Figure 3). When we began this research project, we assumed that the traditional LEPA approach would not supply sufficient water to the pod development zones bordering alternate dry furrows, and were seeking variations of LEPA that would make it workable in peanuts particularly when planted in the same field with cotton.

Our initial certainty that LEPA would not work on peanuts calls to mind a quotation attributed to Charles Kettering to the effect that "Ignorance is not just what you don't know. It's also what you know for sure that is not correct." This statement describes the condition of peanut farmers and those who would presume to advise them, including those presenting this paper.

MATERIALS AND METHODS

AG-CARES is located near Lamesa, Texas in Dawson County (102^{o} West Longitude; 32^{o} 45' North Latitude; 2,965 ft Elevation; 66-year average annual precipitation 17.92 in). The site has an Amarillo fine sandy loam soil (Fine-loamy, mixed, thermic Aridic Paleustalfs) with 0-3% slope. The center pivot irrigation system is nozzled for 425 GPM (3.45 GPM/acre of irrigated area). Peanuts were planted each year to a 40^{o} wedge (approximately 13 acres) under the irrigation system and rotated with cotton. Peanuts had never been planted on this farm until 1995. In 1995, peanuts were on Wedge 1A; 1996, Wedge 4; 1997, Wedge 1A; 1998, Wedge 3; and 1999, Wedge 2A. With the exception of 1997, when the peanut site had also had peanuts in 1995, all field sites were in their initial year of peanut production. Peanut disease levels were so low that no fungicide applications were required during any of the years.

Rows are planted in a circular pattern with 40-in spacings using regular commercial planters. General cultural practices are outlined in Figures 4 and 5. Depending on the crop year, there were from 8 to 16 rows subjected to any one irrigation intensity x application method combination. Peanuts were harvested with a two-row digger. The peanuts were allowed to field dry. Four premeasured plots within each irrigation intensity x application method were threshed with a Kincaid Peanut Thresher to estimate pod yields. Border rows where two treatments met were avoided. We positioned the four sample sites so that they were distributed throughout the field in the down-the-row direction to insure a mix of environmental conditions. The harvest sampling sites were also distributed across-the-row within each treatment area to insure that data artifacts were not produced by relying on the same irrigation nozzle(s) within a given water treatment. This results in multiple subsamples within each treatment area and not true replications or blocks within which treatments were randomized. Repeated Measures techniques were, therefore, used to analyze data. All significance levels discussed are at the 5% probability level. Peanuts from each plot were graded to establish both quality and crop value data.

The irrigation strategy (Figure 6) involved (1) Preseason irrigation if needed to begin the crop year with a full soil profile; (2) Uniform early season irrigation in LESA mode; (3) Replacement of selected portions of Cotton ET every 2.5 or 3.5 days beginning about July 1 and extending to about mid-September (includes LEPA); (4) Reduced application rates until harvest (includes LEPA); and (5) LESA application of 0.25 to 0.50 inch the day before digging if needed. The early LESA irrigation period roughly corresponds to vegetative growth and the July 1 to mid- September period to reproductive development.

Actual irrigation treatments involved combinations of LEPA-AF, LEPA-EF, and LESA applications of different quantities of irrigation water. The relative amount of irrigation water supplied was controlled by nozzle size. Irrigation levels were those needed to replace 125, 100, 75, 50, and 25% of calculated cotton evapotranspiration (ET) in 1995 and 1996; 100, 75, and 50% ET in 1997; 75 and 50% ET in 1998; and 75% ET in 1999. Each irrigation event was designed to replace the specified portions of the calculated ET minus any precipitation since the last irrigation. In 1999, 75% ET levels were applied as LEPA-AF, LEPA-EF, and LESA on single row (SR), double row (DR), and ultra narrow row (UNR) planting patterns.

Seeding rates for the DR and UNR treatments were chosen from those providing favorable results in field trials conducted by the late Dr. A. L. Harrison in South Texas during the late 1950's and early 1960's. Single row plots were planted normally, DR plots were planted by offsetting planter boxes about 4 inches and double planting with each pass in opposite directions; UNRs were planted with a vacuum planter with seven drills spaced 10 inches apart on flattened 80-inch beds. There were essentially three experiments in this test, each watered by the methods described above. Each water application area was divided into three replications with planting patterns randomized within each replication.

RESULTS AND DISCUSSION

Because the quantity of water applied depends on evapotranspiration and precipitation, actual irrigation varied from year-to-year. In general, the highest yielding treatments received approximately 0.50 to 0.75 inches of moisture from all sources per week during the early, vegetative period; 1.50 to 1.75 inches per week during the reproductive growth phase; and 0.50 to 0.75 inches per week during the late season. Figures 7, 8, 9, 10, and 11 show breakdowns of seasonal moisture supply during the 1995 through 1999 crop years, respectively. The reader will also note that after the first two years, we dropped high and low irrigation rates as our knowledge-base increased.

Figure 12 compares the seasonal moisture supply pattern at the 75% ET replacement level and corresponding LEPA pod yield for each year. Our lack of management experience under these experimental conditions during the first year resulted in low yields–probably because of poor inoculation of seed and inadequate early-season moisture. In all other years, our yields were comparable to those of the best area growers.

During the first year, we found no difference between yields for the LEPA-AF and LESA irrigated peanuts (Figure 13). When average yields for irrigation levels were compared across all applications, we found that 125 and 100% ET replacement significantly out-yielded 75% ET replacement, which in turn out-yielded 50 and 25% ET replacement respectively. In some application methods, 125, 100, and 75% ET replacement appeared to have equal yields, but concern that one or more of the LESA yields may have included border rows led us to discredit that result during 1995.

We will examine the 1996 data in more depth, because that year’s results are indicative of most relationships seen in 1997 and 1998, as well. In Figure 15, we see that the LEPA-AF mode significantly out-yielded those of the LESA mode with 5,264 and 4,809 lb/ac, respectively, when averaged for all irrigation quantities. Likewise, LEPA-AF at 5,264 lb/ac significantly out-yielded LEPA-EF at 4,792 lb/ac (Figure 16). When peanut yields are compared for all ET replacement rates for all application methods (Figure 17), we see that in 1996 yields were significantly highest for 125% ET replacement, 100 and 75% ET replacement grouped next, 50% next, and 25% the lowest. As we will see in the next two tables, the increased yield for 125% ET replacement was an anomaly which apparently occurred in the 125% LEPA-EF treatment under the relatively low evaporative demand of much of the 1996 fruiting period.

When only 80" drop spacing data (LEPA-AF and LESA) were considered (Figure 18), 125, 100, and 75% had statistically equal yields ranging from 5,786 to 6,052 lb/ac. Yields for 50% ET replacement (4,439 lb/ac) were significantly lower and 25% ET yields (2,959 lb/ac) lower than for 50%. There was a significant interaction between irrigation intensity and application method for the 80" drop spacing treatments. As shown in Figure 18, 75% LEPA-AF yields were equal to or higher than those for 125% LEPA-AF, 100% LEPA-AF, 125% LESA, and 100% LESA and are higher than those for 75% LESA. Yields for 50% LEPA-AF were less than those receiving more water, but more than those for 50% LESA. Yields for 25% ET replacement by LESA and LEPA-AF were lower than all other treatments.

Figure 19 shows irrigation effects with reference to the two LEPA patterns, LEPA-AF and LEPA-EF. When both LEPA patterns are averaged, we see in Columns 1 and 2 that the 125% ET replacement treatment significantly out-yielded 100 and 75% treatments, as was seen in Figure 17 for means of all application methods compared for response to ET replacement level. But when we examine the means that break out in the interaction of ET replacement level x LEPA drop spacing (Columns 1, 3, and 4, Figure 19), we see the high yields for LEPA-EF (6,603 lb/ac with Duncan's coefficient A) and the reduced yields that result when 75% ET replacement levels are applied in every furrow in LEPA-EF (5,414 lb/ac with Duncan's coefficients BC) as opposed to the usual alternate furrow in LEPA-AF (6,475 lb/ac with Duncan's coefficient A) configuration. Yields for 75% ET LEPA-EF were statistically equal to those for 50% LEPA-AF, with additional significant yield reductions when 50% ET replacement was applied by the LEPA- EF method and when irrigation rates were reduced to 25% ET replacement levels at either AF or EF drop spacings. We, therefore, must conclude that the efficiency imparted by LEPA-AF compared to LEPA-EF or LESA is less important at relatively luxurious water application rates than at barely-optimal (75% ET replacement) or sub-optimal rates (50 and 25% ET replacement).

We have summarized the impact of percent ET replacement for the 80" drop spacing applications during all five crop seasons in Figures 20 and 21. As we look across the years, 75% ET replacement was generally adequate for high yields (Figure 20). In general, yield breaks off when ET replacement rates drop below 75%. Although the data is not shown, we have noted that grades generally break when irrigation rates are less than 50% ET replacement. As discussed for the 1996 results, 75% ET replacement by LESA or LEPA-EF placement often reduced yields compared to the 75% ET LEPA-AF applications. In Figure 21, we see the yield losses associated with LESA vs. LEPA-AF application. These generalizations are apparently because of the increased application efficiency of the barely-optimal rate using LEPA-AF. LEPA-EF loses efficiency by wetting both furrows, thus exposing more of the water to surface evaporation with less available to move into the soil. LESA loses efficiency both from wetting more surface area and also by some evaporative losses before reaching the soil, albeit less than with impact sprinklers or others that deliver the water from a point higher above the canopy.

All the above discussion still does not address the question of why LEPA-AF works, when one experienced in the need for some level of moisture in the pegging zone would intuitively doubt the ability of this application method to achieve that requirement. We believe that irrigation/planting pattern research conducted in 1999 helps us understand what is happening under the TSHP peanut growing conditions. Figure 22 shows the irrigation application methods applied to the planting patterns shown in Figure 23, single row (SR), double row (DR), and ultra narrow row (UNR). Statistics on planting pattern–including row spacing, seed drill spacing, number of seed per acre, number of seed per square foot, number of seed per foot within the seed drill, and space between seed within the row–are shown in Figure 24. SR and DR peanuts produced equally high yields when averaged across irrigation application methods, but UNR yields were significantly lower (Columns 1 and 2, Figure 25). When averaged across all planting patterns, LEPA-EF and LESA significantly out-yielded LEPA-AF (Columns 3 and 4, Figure 25). When we look at the data as the effect of planting pattern within each irrigation method (1st row of data, Figure 26), we see that SR and DR yields were statistically equal with LEPA-AF, but UNR was dramatically and significantly lower (only 3,855 lb/ac) compared to well more than 5,000 lb/ac for the other planting patterns. Under LEPA-EF (2nd row, Figure 26), yields for all planting patterns were equal. Yield response to planting pattern with LESA irrigation was similar to that for LEPA-AF with SR and DR out-yielding UNR, but UNR yields were not nearly as low as with LEPA-AF. If we analyze the yield data for all planting pattern x irrigation method combinations (Figure 27), we find that yields for LEPA-AF x SR, LEPA-EF x SR, LEPA-EF x DR, LEPA-EF x UNR, LESA x SR, and LESA x DR had statistically equal yields of greater than 5,800 lb/ac. LEPA-AF x DR had significantly lower yields of 5,238 lb/ac; LESA x UNR had still lower yields of 4,628 lb/ac; and LEPA-AF x UNR had the lowest yields of 3,855 lb/ac. Grades were significantly lower in UNR compared to the SR and DR planting patterns, but were unaffected by application method (Figure 28). Throughout most of the growing season, the UNR plots appeared to be water-stressed. The worst stress was observed in the LEPA-AF plots, in which many plants in the area corresponding to the dry furrow were essentially dead. All UNR plots required additional water on the day before digging and still suffered more digging problems.

CONCLUSIONS

We believe the planting pattern x irrigation method results for 1999 discussed above explain why LEPA-AF is effective as follows: (1) Peanut plants in the TSHP region are smaller than in more warm, humid, lower-elevation growing areas, even for the same runner cultivars; (2) Fully-developed peanut pods are restricted to perhaps a 12-inch band centered on the line of plant crowns at the center of the raised bed, even on runner cultivars; (3) There is sufficient lateral movement of water from the alternate watered furrows to keep the narrow pod-development zone sufficiently moist, even on the dry-furrow side in single row peanuts in the sandy-loam soil found at AG-CARES; (4) When the pods toward the dry-furrow are moved farther from the watered furrow as in DR and UNR, the pod-development zone moisture is not adequate for normal development, thus reducing yields; (5) If plants were larger with a wider expanse of fully- developed pods as is seen in warm, humid, lower-elevation growing areas, LEPA-AF might not work well; (6) Spreading-type peanuts in the TSHP and similar growing areas may not respond favorably to multiple-row planting patterns as is seen in warm, humid, lower-elevation growing areas.

Our five years of irrigation experiments on runner peanuts at AG-CARES have led us to conclude:

- High-frequency, alternate-row LEPA application of irrigation water (using drag socks) supplied adequate water and maintained adequate pod-zone moisture during the July-mid September period, even with circular-row planting (Figure 29).

- Calculated cotton evapotranspiration (ET) served as a reliable guide for irrigation water quantities (Figure 30).
- With few exceptions, 0.75 ET replacement was adequate (Figure 30).
- Alternate-furrow LEPA tended to come closer to fulfilling plant needs when water application rates were inadequate--0.50 and 0.25 ET replacement (Figure 30).
- Our results confirm that there is no realistic opportunity for producing food-quality peanuts without irrigation in the Texas Southern High Plains growing region (Figure 31).
- To date, we have found no advantage to ultra narrow row planting patterns for peanuts under our growing conditions (Figure 31).