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GENETIC VARIABILITY FOR WATER USE EFFICIENCY

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Abstract

The physical environment largely determines crop water use, when the soil water supply is adequate. Plant productivity within a given physical environment and water supply differs among species and possibly within species. Plant productivity per unit available water is defined as water use efficiency. We have evaluated the yield response of numerous cotton cultivars to a wide range of water supplies within each year over the past seven years. This paper summarizes our results. Water use efficiency defined as lint yield per unit water supply (kg lint/mm water) has a very strong environmental effect varying by nearly two fold from year-to-year. There were genetic differences in WUE between pickers and strippers with the pickers having a slight advantage. No consistent response to growth habit was observed. The results of this long-term study suggest that the physical environment dictates water use efficiency of cotton. However, genetic differences do exist for WUE, although fairly small.

Introduction

Lack of an adequate water supply throughout the life cycle of most crop plants represents the single greatest limitation to attainment of genetic yield potential. Crop water use is a function of the potential evaporation rate defined by the physical environment and the interaction with the crop (leaf area index). Water use efficiency is commonly defined as plant productivity (biomass, economic yield) divided by the total water supply or the water supply available to the growing crop. Major emphasis has been placed in recent years to increase the efficient use of water. This is largely an engineering and water management effort including conservation tillage, irrigation system design and irrigation scheduling. Technology exists to increase the efficient use of our total water resource. The next step is to exploit possible genetic variation in biological water use efficiency. Large differences exist among species, but do within species differences exist. Krieg (2002) analyzed the genetic by environment interaction for yield using variety test data from Texas for the past 10 years and 15 sites across the various cotton growing regions in Texas. The results indicated that average yields were only 20-25% of maximum yields within each environment. The results also indicated that picker types were able to respond to better environments to a greater extent than stripper types.

This study evaluated the opportunity for genetic variation in water use efficiency between strippers and pickers and among cultivars grouped by growth habit within each type. The study has been conducted over a seven-year period using a wide range of water supplies within each year.

Materials and Method

This study was conducted over the past seven years at the Crop Production Laboratory in Terry County, Texas. The soil texture is a fine sandy loam, typical of the vast cotton production area in West Texas. A wide range of water supplies was used each year ranging from dry land conditions to supplemental irrigation using different volumes and frequencies within each year. A center pivot operating in the LEPA mode (circular rows and drops to the ground) was nozzled to provide different volumes per application. Volumes ranged from 2 gallons per minute per acre (GPMA) to 5 GPMA, which is equivalent to 0.10 in/day to 0.26 in/day. Frequencies ranged from 3 to 6 day intervals for each volume. Within each water supply, numerous picker and stripper cultivars were evaluated. Total water supply was defined as stored water at planting plus in-season rainfall and irrigation water. Yield was determined as a function of all individual yield components. Water use efficiency was expressed as a function of total water supply and irrigation water supply.

Results and Discussion

Lint yield (kg lint/ha) ranged from less than 250 kg/ha to over 2000 kg/ha over the course of this study. Yields increased as total water supply increased (Figure 1); however, large variation existed within a water supply reflecting a large year effect and varieties being evaluated. Genetic differences in yield response to water supply was observed with pickers being superior to strippers especially at the higher water supplies. Within pickers, the degree of indeterminacy also resulted in differences in yields especially at the lower water supplies. No growth habit differences were evident for the stripper-types.

Large environmental variability existed in water use efficiency (lint yield per unit water) when averaged across genetic types and water supplies within each year (Figure 2). Water use efficiency ranged from 1.1 to 2.4 kg lint/mm water with 2001 being the best year. Irrigation water use efficiency paralleled total water use efficiency but was about twice the magnitude. Irrigation water use efficiency ranged from 2.2 to 3.8 kg lint/mm irrigation water. In English terms this represents a range from 50 pounds lint/inch of irrigation water to 86 pounds/inch. Even at 50 cents per lint pound, this represents a significant return on investment.

The genetic variation in water use efficiency in Figure 3 reflects the yield responses and suggests that pickers are superior to stripper types. The growth habit differences were less obvious. The moderately-determinate pickers were superior to the determinate pickers at low water supplies, but were equivalent at higher water supplies. The reverse trend existed for the stripper-types. The magnitude of the genetic variation in water use efficiency is approximately 25% in this set of commercial varieties. This degree of variation is worthy of exploitation.

Summary

This study evaluated the opportunity for genetic variation in water use efficiency among cotton cultivars differing in picker versus stripper types and degree of indeterminacy within each type. Environmental differences in water use efficiency were quite large. However, genetic differences did exist. Pickers were more efficient than stripper types. The opportunity for selecting and developing more water use efficient varieties does exist and should be exploited.

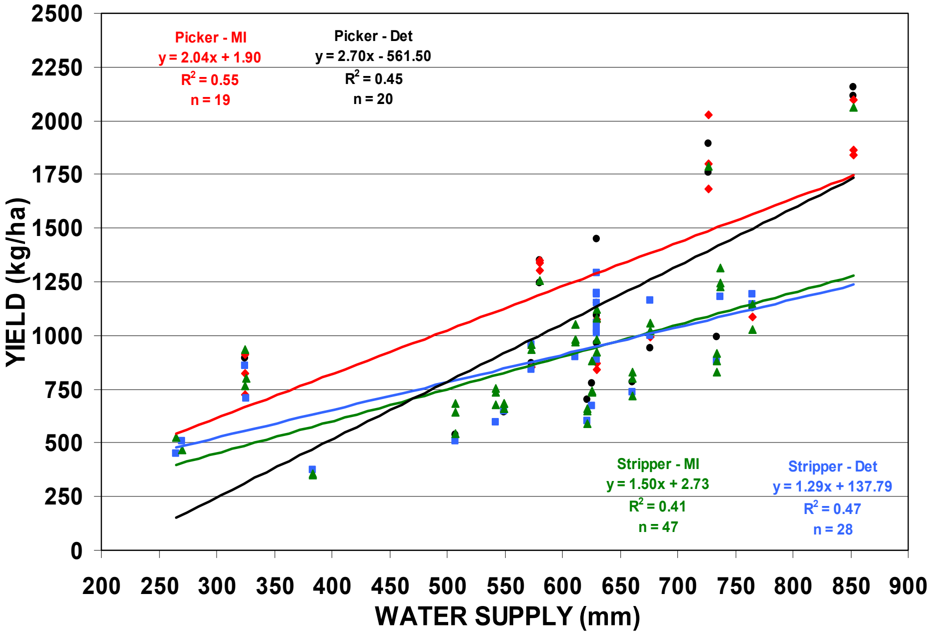

Figure 1. Cotton yield response to water supply within genetic types.

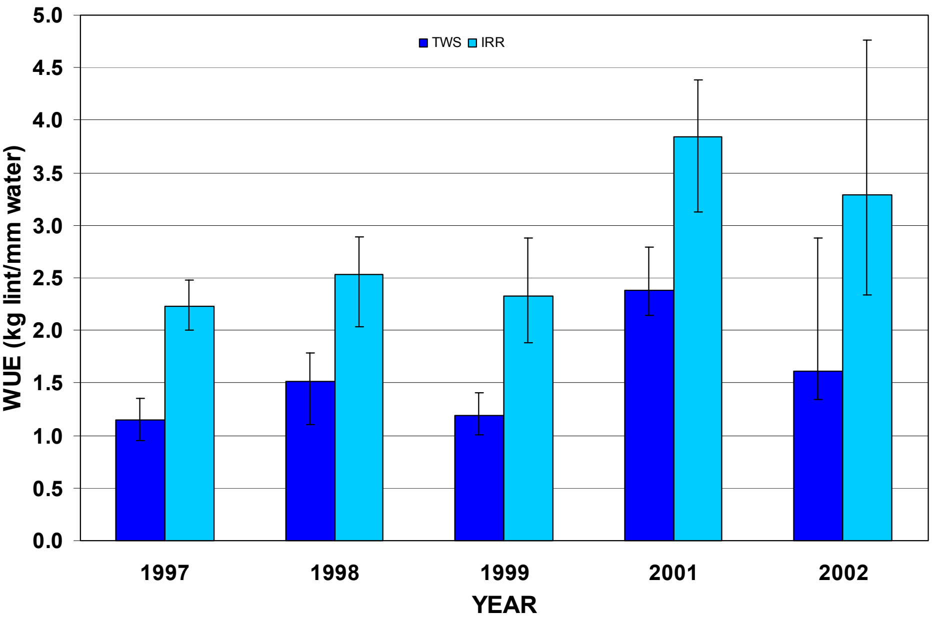

Figure 2. Environmental variability of total water use efficiency and irrigation water use efficiency as a function of year across all water supplies and genetic types (maximums and minimums for each year).

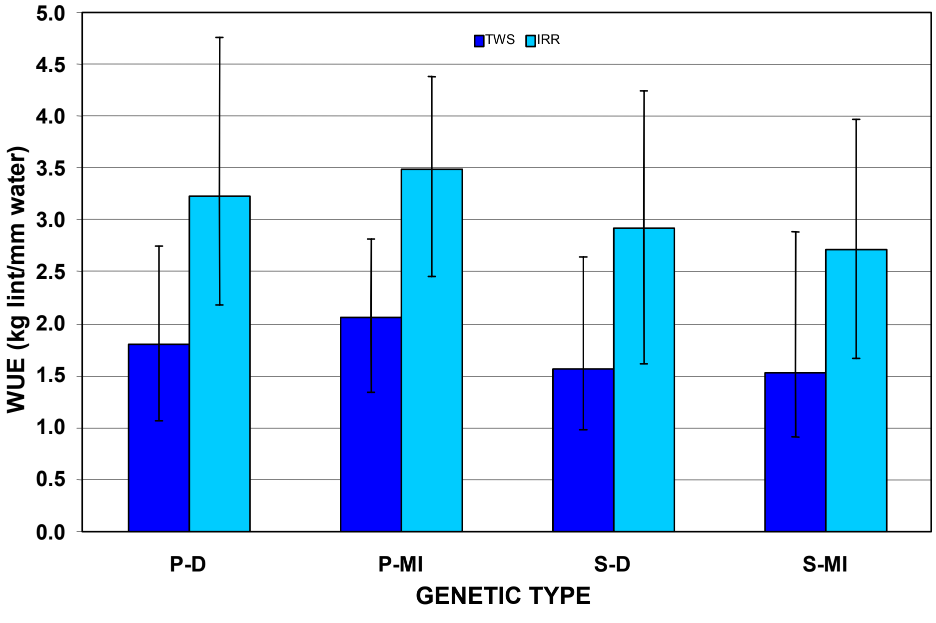

Figure 3. Genetic variation in water use efficiency across environments (P= Picker, S= Stripper; D= Determinate, MI= Moderately-indeterminate).