EFFECT OF CONSERVATION SYSTEMS AND IRRIGATION ON POTENTIAL BIOENERGY CROPS

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SUMMARY

Renewable energy production in the United States should increase due to economic, environmental, and national security concerns. In the Southeastern US, annual cellulosic crops could be integrated in rotation systems to produce biofuels. An experiment conducted in South Central Alabama evaluated three sorghum varieties (1990, SS506 and NK300) and a corn hybrid (31G65) under different irrigation and tillage treatments. SS506 showed higher biomass production at 14 weeks after planting, but 1990 had higher yields after the 18th week. Irrigation affected yields positively. Tillage showed no differences in yield. Thus, a conservation system was recommended due to productivity and environmental concerns.

INTRODUCTION

Seeking alternative and renewable sources of energy is necessary due to oil price fluctuations and environmental concerns. Additionally, Central and South Alabama agriculture has been negatively affected by drought conditions over the last several years which have dramatically reduced corn production. For these reasons, sorghum may be a reasonable alternative as an energy crop in this region, because it is considered drought resistant (Habyarimana et al., 2004). Sorghum could be integrated in a conservation system as part of a crop rotation with typical cash crops (peanuts, cotton), where part of its biomass would be used as soil cover and any additional amount of biomass would be harvested for potential biofuel production. While much emphasis has been placed on perennials for biofuel production, annual crops could provide a major source of biomass for cellulosic ethanol production. These annual crops for bioenergy production have largely been ignored. Because summer days in Southeastern U.S. are extremely long, a photo-sensitive variety (1990), which needs less than 12 hours and 20 minutes of daily light to flowering, is presented as a potential alternative. Thus, this variety is described as having tall plant height from 10 to over 12 feet, good stalk strength, very high tonnage yield performance and average stalk sweetness (Sorghum Partners, 2008)

MATERIALS AND METHODS

In order to evaluate sorghum and corn biomass quantity for potential biofuel production, and to determine the effect of tillage and drought stress on sorghum and corn biomass production for different tillage management systems, an experiment was begun at the E.V. Smith Research Station, Shorter, AL (85º :53’50” W, 32º:25’22” N) in April, 2008. The soil at the experimental field was classified as fine-loamy, kaolinitic, thermic, typic Kanhapludults included in Marvyn

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series. The total field was set with rye cover (*Secale cereale L.*) before planting corn (*Zea may L.*) and sorghum (*Sorghum bicolor L.*).

Three different sorghum varieties were evaluated in this experiment; (1) grain sorghum, NK300 (GS), (2) forage sorghum, SS506 (GS), and (3) photoperiod-sensitive sorghum, 1990 (PS). Also, the hybrid corn 31G65 was included in the experiment which was classified as drought tolerant with high plant height and residue production (Pioneer, 2009).

The plots were managed with two different irrigation treatments: non-irrigated and irrigated. In the irrigated plots, water was applied in appropriate timing and amounts to provide plants with good water availability during the growing season. Additionally, two different tillage systems were applied: conservation system and conventional system. Conservation plots received in-row subsoiling 12 in. deep while conventional plots received both in-row subsoiling 12 in. deep and discing 6 in. deep.

The total number of experimental plots were 64, composed of 4 crops (GS, FS, PS and corn) x 2 irrigation treatments (non-irrigated and irrigated) x 2 tillage systems (conservation and conventional) x 4 replications. Figure 1 shows how the experiment was arranged in the field.

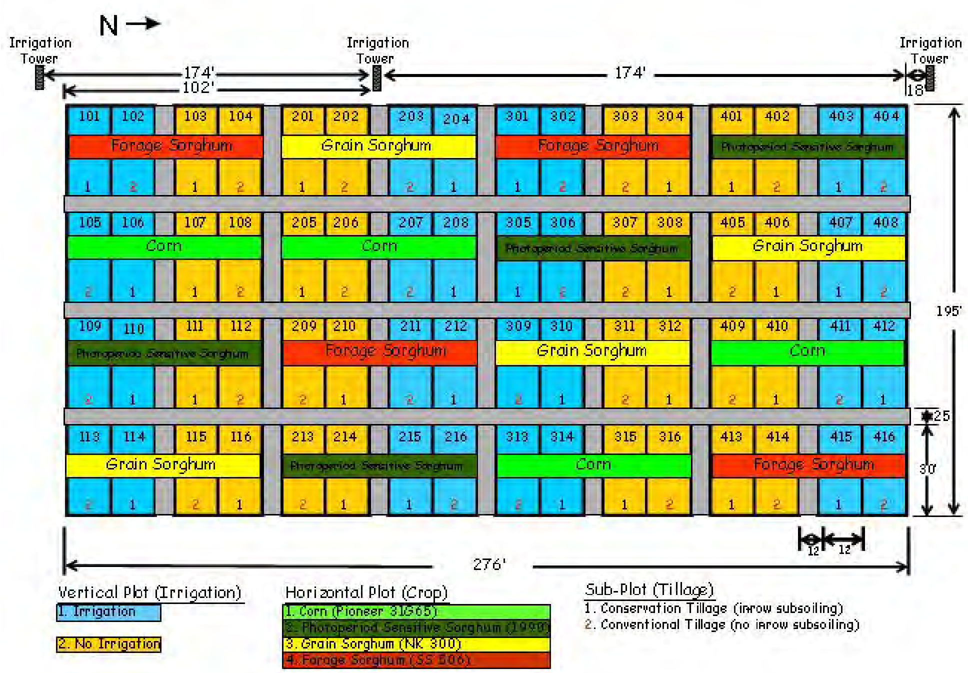

Figure 1: Experiment layout illustrating the 3 treatments arrangement at field.

Plots with the same irrigation treatment were grouped vertically, but plots under different irrigation regimes were separated by borders. Both plots and borders were 12 ft. wide and 30 ft. long, in which 4 rows were cropped 3 in. spaced. However, all samples and readings were collected from the two middle rows of each plot.

Dry aboveground biomass samples were collected during three different time periods: 14, 18, and 24 weeks after planting. Five ft. of biomass samples were harvested from each two middle rows. Corn and GS biomass samples were not collected at the 24th week, because those crops were terminated at 18 weeks after planting. The total harvested dry aboveground biomass weight of each plot was recorded. Samples for each plot were collected and dried at 55º F until constant weight to estimate dry aboveground matter.

Plant height was measured in 5 different time periods, where 2 time periods were performed early during the growing season at 6 and 9 weeks after planting and the 3 remaining time periods were performed during the dry aboveground biomass collection. Ten different plants in the two middle rows of each plot were randomly selected and measured.

Statistical analyses were performed in a strip-split-plot design with crop as horizontal plots, irrigation as vertical plots and tillage as sub-plots. The predetermined significance level was $P \leq 0.10$ and Fisher's least-significant-difference test (LSD) was performed for means comparisons. The data were analyzed with GLM procedure using software SAS 9.1. Thus, regression analyses were also performed for the 4 different crops under the different interactions over time between irrigation and tillage treatments with GPLOT procedure.

RESULTS AND DISCUSSION

DRY MATTER

Comparing each time period of dry matter collection separately, all crops were statistically significant different from each other at 14 weeks after planting (Figure 2). FS showed the highest dry matter yield (9.5 tons acre^{-1}) followed by PS (8.1 tons acre^{-1}), GS (5.5 tons acre^{-1}) and corn (3.2 tons acre^{-1}). Irrigation also showed statistical differences with irrigated plots having higher yields than non-irrigated plots. The overall means for irrigated and non-irrigated plots were 7.4 tons acre^{-1} and 5.8 tons acre^{-1}, respectively.

Results from dry matter collected at 18 weeks after planting showed statistical differences for different tillage systems and irrigation treatments as well as for the interaction between these two factors. Different crops showed significant difference in dry matter (Figure 2), where PS showed the highest yield (11.9 tons acre^{-1}) followed by FS (10.2 tons acre^{-1}), GS (5.9 tons acre^{-1}) and corn (4.0 tons acre^{-1}).

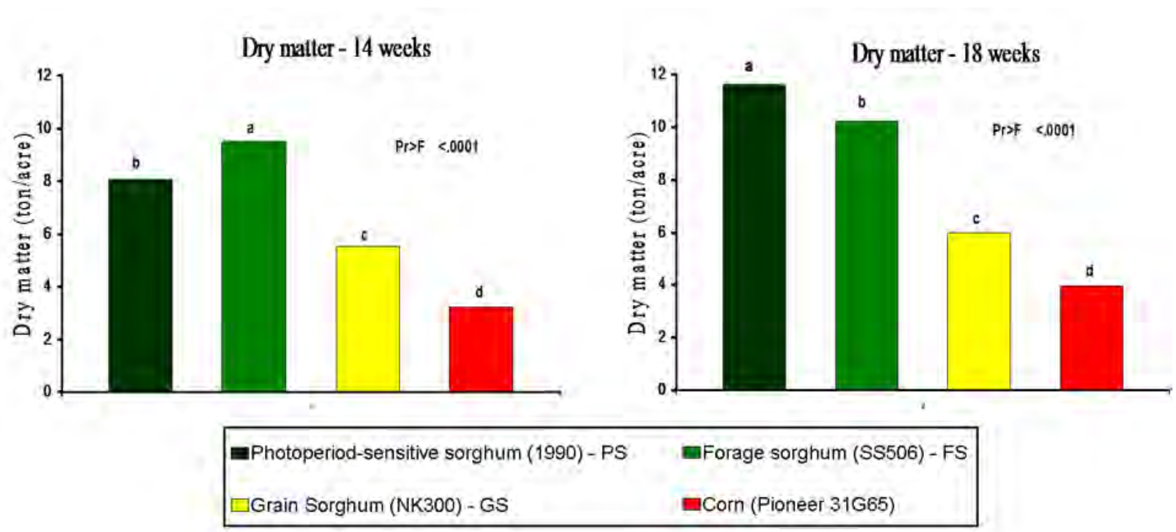

Figure 2: Dry matter yield at 14 (left) and 18 weeks (right) after planting.

Comparing the dry matter results for different tillage systems between the 14th and 18th week, the PS became more productive between 14 and 18 weeks after planting. Therefore, photosensitive sorghum has the highest biomass production potential during longer growing periods in US Southeast. Irrigated plots had higher yield than non-irrigated, 9.0 and 6.8 tons acre^{-1}, respectively.

Additionally, an interaction between tillage system and irrigation was found (Figure 3) and the results showed that all rainfed sorghums produced more biomass than irrigated corn. Therefore, sorghum showed higher drought resistance than corn. This statement was explained based on the different ability of sorghum and corn to extract water from soils. Corn absorbed water from top soil (0-18 in.) while sorghum absorbed water in deeper soil layers (18-53 in.), which had more available water for plants (Farre & Faci, 2006).

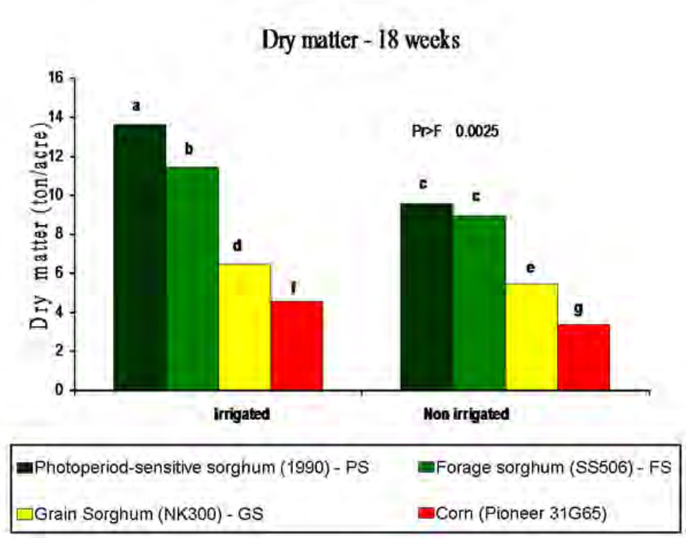

Figure 3: Dry matter yield for cultures x irrigation at 18 weeks after planting.

The dry matter collection at 24 weeks after planting was performed only in PS and FS plots, because the other cultures were mature and terminated at 18th week. For this reason, the total plot numbers were reduced in half (32 plots), which decreased the statistical power to detect significant differences (less replications, reduced degree of freedom) at 24 weeks after planting. Therefore, no differences were observed for any factor. However, PS showed numerically higher yields than FS, 13.4 and 10.70 tons acre^{-1}, respectively which was a difference of 2.7 tons. This was a greater difference than the advantage that PS showed at 18 weeks which was 1.7 tons.

The two different tillage treatments were not found to be different at any period time. Different results was reported by Cogle et al. (1997) which observed higher sorghum dry matter yields among three different tillage managements (zero-tillage, shallow tillage – 4 in. and deep tillage – 8 in.) applied on corn and sorghum fields. However, conservation tillage should be recommended in both cases because fuel, compaction, and erosion are all reduced using conservation technologies.

PLANT HEIGHT

The evaluated tillage systems showed different growth over time when analyzed in each irrigation x tillage treatment (Figure 4). In all scenarios, plant height followed the same trend as total biomass. Corn and FS showed higher growth until 9 weeks after planting. PS and FS overcame corn at 14th week. GS showed lower plant height values than corn during the entire season. Controversially, GS produced more dry matter than corn due to its ability to produce more leaves, which resulted in more dry matter accumulated than corn.

In irrigated treatments within any tillage, PS became statistical different from FS at 18 weeks after planting, but they were not different in non-irrigated treatments. However, water availability may have more affect in PS development than FS due to significantly greater biomass production when irrigation was provided.

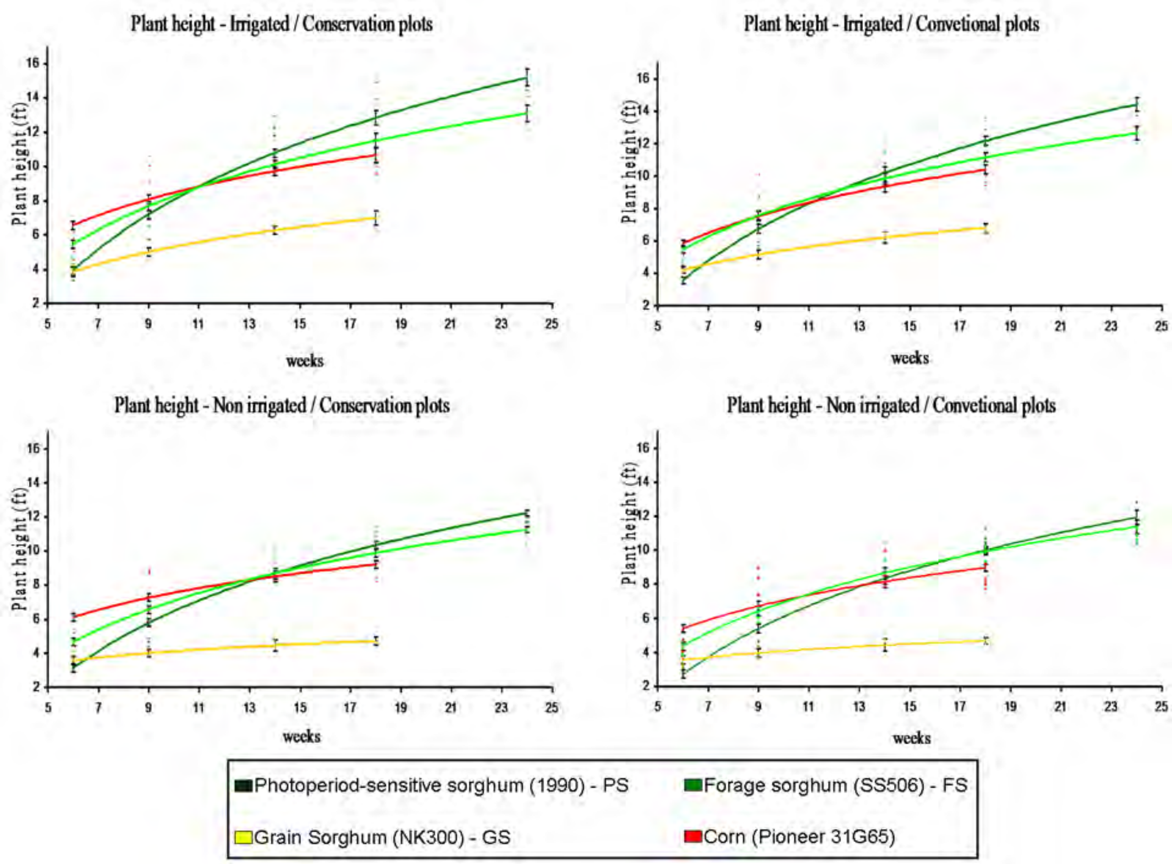

Figure 4: Plant height of cultures over time in each tillage x irrigation treatment.

CONCLUSIONS

In order to achieve the highest biomass yield for biofuels production, PS showed the greatest potential by yielding more than 13 tons per acre. At 14 weeks after planting, FS had the greatest biomass, but PS overcame the difference and exceeded FS during the later growing weeks of the season.

Irrigation increased biomass production in any period time for all tillage systems. However, PS, FS and GS showed higher yields in rainfed conditions than irrigated corn. Therefore, any sorghum, especially PS, should be recommended not only for higher biomass production, but also for reduced water use.

Different tillage systems did not affect biomass production. Therefore conservation tillage should be recommended because fuel, compaction, and erosion were all reduced using conservation technologies.

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