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Evaluation of Switchgrass Cultivars and Cultural Methods for Biomass Production in the South Central U.S.

Consolidated Report 2002

W. Ocumpaugh, M. Hussey, J. Read, J. Muir, F. Hons, G. Evers, K. Cassida, B. Venuto, J. Grichar, C. Tischler

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UT-BATTELLE

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EVALUATION OF SWITCHGRASS CULTIVARS AND CULTURAL METHODS FOR BIOMASS PRODUCTION IN THE SOUTH CENTRAL U.S.

CONSOLIDATED REPORT 2002

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CONTENTS

1. TEN-YEAR (1992–2001) SUMMARY

Since 1992, we have been evaluating Switchgrass for biofuel development in Texas (since 1997 in Arkansas and Louisiana). We have evaluated various fertility requirements, planting densities, harvest frequency, optimum harvest dates, alternative cultivars/breeding lines, and we have completed considerable research on issues relating to stand establishment. Soil quality responses have been monitored at most locations. We can write a Management Plan to optimize yield (once established). In late 1999 our research program underwent a review by the DOE Project Manager, we were allowed to restart the work on selecting for and evaluation of seed and seedling traits for stand establishment. We have made good progress, but there are still major efforts needed to determine the appropriate seed and seedling traits needed, and to develop the "science-based" Best Management Practices (BMP) for switchgrass establishment in the lower South. There is no herbicide that will consistently work on the Lowland ecotypes. This suggests one of two things, first that the herbicides are phytotoxic to lowland switchgrass, or second that the weed competition is only part of the problem. The herbicides that work on the Upland ecotypes in the Mid-West appear to have a level of phytotoxicity that limits their use on the Lowland ecotypes. Insects have been implicated as part of the problem, but we have used soil implant insecticides in combination with a number of herbicides, with no positive results. Several projects in the lower South have indicated Methyl Bromide is the only consistent means of assuring a stand. This to suggest that there may be more than just weeds (and insects) involved in the problem of getting a stand. A set of soil samples taken in the fall of 2001 indicates a negative relationship between nematode populations and stand persistence among different cultivars planted in 1997. Hence we believe that there are a number of issues relating to seedling establishment in need of serious study at the very basic level to solve the problem of switchgrass establishment. We are certain the problem is as severe in south-central region as it is anywhere in the country and it will require a multi-disciplinary team to address this problem from several perspectives.

Several other issues that will impact the success of the DOE switchgrass effort need attention. These include further documentation of the soil quality and soil carbon issues; the science of seed production; and the potential to use legumes to reduce the N-fertilizer input and enhance wildlife habitat.

What We Know About Switchgrass after Ten Years of Research in the South Central Part of the USA

"Alamo" switchgrass is our best variety in the long-term studies. Most of Taliaferro's "Southern Lowland" selections continue to show promise, but are not consistently superior to Alamo. The "Upland" types are ALL inferior to the Lowland types, with the yield difference in the 2X to 3X range between these two types. Rainfall during May, June and July appear to very important in determining variation in yield from year to year and location to location. Limited work with one or two single irrigation applications support this information on rainfall in the late spring & early summer.

Research has documented that a single harvest taken near the end of the growth period optimized yield. Response to fertility has been studied at five different locations with multiple years at each location. Switchgrass does not respond to P fertility, but responds to N in either a linear or quadratic function, depending on the year, location, and amount of N applied. When high rates of N are used, N response has been quadratic, with the fitted data indicating yields maximize at about 165 kg of N per hectare, but since these responses are quadratic, economic maximums are closer to 120 kg/ha. Lodging can be quite severe at some sites when the N rates are pushed beyond the 120 kg/ha. Yield losses after mid-August are in the 10 to 11 kg/ha/day range. Delaying harvest by 100 d results in yield losses of 1000 to 1100 kg/ha DM. This is important to know, as all fields cannot be harvested at the optimum time. Dry matter content goes up with delayed harvest to the point that direct cutting may be possible if soil conditions will permit. There is also a drop in some nutrient concentrations as fall harvest date is delayed, particularly P, K, Mg, and on a more limited basis N and S. This loss in mineral concentration with delayed fall harvest should translate into improved fuel quality AND reduced mineral removal.

Soil Quality Changes Associated with Switchgrass

Soil samples under switchgrass, other forage grasses, cultivated cropping systems, and forest were collected annually. Sampling depths at all locations were 0 to 5, 5 to 15, and 15 to 30 cm. Soil characteristics determined included soil organic C and total N, initial inorganic N, microbial biomass C and N, soil C and N mineralization, basal soil respiration, and particulate organic matter (POM)-C and -N .

Soil organic C (SOC) was greatest under long-term grasses (Coastal bermudagrass, bahiagrass/fescue) and forest, intermediate for switchgrass, and lowest for the cultivated treatments. When soil samples for the cultivated wheat/cotton treatment at Dallas were compared with those from Alamo switchgrass planted in 1992, switchgrass planted in 1997, and long-term (~ 30 years) Coastal bermudagrass, an additional 30,000, 22,000, and 41,000 kg C per hectare-30 cm were noted for the latter three treatments. When the increase of additional SOC between switchgrass planted in 1992 vs. 1997 was computed, a SOC accretion rate of 1,600 kg C per year to a depth of 30 cm was determined. Comparing SOC in the cultivated wheat/peanut treatment at Stephenville to Alamo switchgrass planted in 1992, switchgrass planted in 1997, and long-term coastal bermudagrass at that location resulted in SOC increases of 11,000, 5,000, and 25,000 kg C per hectare 30 cm, respectively. The annual increase in SOC under switchgrass was estimated to be 1,200 kg C per hectare 30 cm at Stephenville. Smaller increases with switchgrass compared to the cultivated grain sorghum-wheat-soybean treatment were noted at College Station, possibly because of the large residue-C return with this rotation.

Measurements of active fractions of the soil organic matter pool, such as soil microbial biomass C and mineralizable C, were more consistent in trends and absolute amounts within locations across years than was SOC. Various measurements of active fractions and microbial activity were strongly correlated. The fraction of SOC as soil microbial biomass C is frequently used as an indicator of changing soil quality. In this study, the fraction of SOC as POM-C appeared to be a more robust indicator of soil quality and also better correlated with other soil quality attributes. POM-C is more quickly and easily determined than soil microbial C and other longer-term methodologies and, therefore, might be more readily and widely determined. The fraction of SOC as POM-C was either greatest or next to the largest for switchgrass compared to other vegetation treatments across all locations, indicating improvement in soil quality with this treatment.

Modifying Switchgrass to Improve Stand Establishment

Seed and seedling traits have been modified through appropriate evaluation and selection procedures. There is variability within Alamo switchgrass for a number of traits including crown-node placement, seed dormancy, and seedling vigor/seedling mass. A germplasm release and a number of greenhouse and field studies with this selection verify that the

Low-Crown node placement is a desirable trait. Progress and selection for Low seed Dormancy has been more difficult to document, as the environment under which the seed is produced appears to have as much impact on seed dormancy as genetics, but we believe that true genetic progress has been made in selecting for this trait. Selection for high seedling mass at 2 weeks after emergence is currently underway. However, we are only at the stage of making our second cycle of selection as this process requires progeny testing after each cycle of selection. Seedling mass at 2 weeks after emergence is not related to seed mass, so indirect selection for seed mass is of limited value. Growth Chamber studies with seed from several hundred individual clones has revealed superior genotypes for seedling mass at 2-weeks post emergence. Ideally, we think we should have Low Dormancy, Low Crown, and High Seedling Mass traits in one germplasm to maximize the benefit.

Developing Best Management Practices to Assist in Switchgrass Establishment

In Growth Chamber studies, emergence rate increased as temperature increased but temperature did not affect total emergence by 28 days after planting (DAP). By 8 DAP, seedling emergence in the 86/68^{0}F temperature treatment was near maximum emergence and was twice that of the 77/59^{0}F treatment. None of the seedlings in the lowest temperature treatment had emerged by this time. The ranking of varieties for emergence rate and total emergence was Lowdorm > Alamo > Blackwell. (The Lowdorm switchgrass used is an intermediate stage of what we think we can develop for maximum response) The Lowdorm used had a greater and more rapid seedling emergence than the other varieties. Maximum emergence was reached at 16 DAP for the southern Lowland ecotypes Lowdorm and Alamo, and at about 24 DAP for the northern Upland ecotype, Blackwell. In much of the Southeast, temperatures from April through October should be adequate for total switchgrass seedling emergence. However emergence would be more rapid if planted in warmer temperatures from May through September if moisture were not limiting. The more rapid emergence should also make the switchgrass seedlings more competitive with weeds. Lowdorm switchgrass should be planted in the southeastern USA because of greater and more rapid emergence.

Greenhouse studies using different soil textures, and watering patterns, and repeated at different times of the year with Alamo switchgrass has highlighted some issues related to conditions that favor switchgrass establishment. In sandy soils, moisture levels were frequently near 0% at the 10- and 14-day watering intervals with maximum moisture levels of 10 to 15% at the 3 day watering interval. Moisture levels in the silty loam were never below 5% with maximum levels from 20 to 25% at the 3-day watering interval. The clay soil had the greatest moisture retention with minimum soil moisture levels of 10% with levels up to 30% for the 3-day watering interval. There were not any consistent differences among soils for switchgrass emergence. There was a tendency for switchgrass to have greater and more rapid emergence when watered at least every 7 days, especially under the high temperatures during a July greenhouse run. Seedling survival was always good in clay soils regardless of watering interval because of its high moisture holding capacity. Seedling survival decreased rapidly in the sandy and silty loam soils when watered only every 10 or 14 days. A watering interval of 7 days or less was necessary for seedling survival of 90% or more in all soils. The general trend was for seedling development to be more advanced and shoot and root weights to be heavier in the sandier soils than in the silt loam and clay soils if the seedlings survived. The silt loam cracked vary badly, especially at the 10 and 14 day watering interval, which limited seedling growth. There was a general decline in shoot weight as the watering interval increased. There was a general decline in root development as watering interval increased. If watered every 3 days, there were no differences among soils. The trends in root weight were identical to that of shoot weight with differences among soil series at every watering interval. As with the other seedling traits, there was a general decline in root weight as watering interval increased, especially at the higher temperatures in the July run. Root weights were a greater in the sandy soils if the seedlings survived.

The sandy soils are representative of most soils found in East Texas. Switchgrass seedling growth and development was good in these soils, but it was very critical that the seedlings received water every 7 to 10 days. Switchgrass should be planted from late April through mid-May when temperatures are mild and rain chances are good. The Necessity of rainfall at least every 10 days is one of the factors for unreliable switchgrass establishment on sandy soils in the Lower South

Herbicide Impacts on Getting a Stand

We have evaluated a number of herbicides in the field, and some show limited potential to be useful. However; preliminary greenhouse work with some of these same herbicides applied after a band of activated carbon was applied over the seeded row show the most promise for a reliable system to control the weeds and not reduce switchgrass seedling growth.

Alternate Species have received Limited Evaluation

Arundo donax, commonly called Giant Reed in Texas, was harvested from some areas that had been established for several years as well as very limited evaluations from plots established specifically for research. Yields from newly established plots are not all that impressive (about 9000 lbs/A @ Beeville) when establishment year and second year biomass was harvested in mid-winter. But earlier yields from established stands (also higher rainfall) provided 10,000 to over 20,000 lb/A. In all the tests conducted, there was no significant response to N-fertilizer treatments.

Desmanthus bicornutus, and experimental perennial warm-season legume was seeded at two locations, but good stands were obtained only at Beeville. Plots harvested in October of 2001 indicated that there is minimal response to P fertilizer, 3 lb seeding rates were superior to 10 and 20 lb-rates, and that the later maturing lines produced more than the early maturing lines. Yields in the range of 6000 to 7000 lbs/A were harvested. We have not tried to interseed this legume into switchgrass, but it grows as tall as switchgrass, and may prove to provide all the nitrogen needed for sustainable biomass production with little or no applied N-fertilizer.

Publications

Section 4 of this report lists the publications associated with this project. The total publications for the 10 years is 155, which includes 46 refereed Journal papers, 4 Book Chapters, 23 Proceedings papers, 7 Grant reports, 4 Masters Theses, 3 Ph.D. Dissertations, 44 Abstracts, 19 Presentations, and 5 Field Day reports. Of these 155 total, 86 publications have a 1998 or later date, including 32 of the 46 refereed Journal papers.

2. FIVE-YEAR (1997–2002) SUMMARY

"Alamo" switchgrass is our best variety in the long-term studies. Most of Taliaferro's "Southern Lowland" selections continue to show promise, but are not consistently superior to Alamo. The "Upland" types are ALL inferior to the Lowland types, with the yield difference in the 2X to 3X range between these two types. Rainfall during May, June and July appear to very important in determining variation in yield from year to year and location to location. Limited work with one or two single irrigation applications support this information on rainfall in the late spring & early summer.

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3. FIVE-YEAR (1992–1996) PROJECT SUMMARY

INTRODUCTION

Research on switchgrass as a bioenergy crop at the Texas Agricultural Experiment Station focused on three tasks: (1) evaluation of experimental and commercially available switchgrass germplasm at multiple sites, (2) methods to reduce post-harvest seed dormancy and improve seedling establishment, and (3) defoliation and soil fertility management.

Task 1. Evaluation of switchgrass cultivars at multiple sites.

Objective: To obtain data on adaptation of available cultivars and experimental germplasm.

Nine cultivars were established at Stephenville, Beeville, Dallas, Knox City, Temple, and College Station in 1992. The trial at Stephenville was reestablished in 1993. A single cut (October or November) or two-cut (June and November) harvest system was imposed on all cultivars in 1993, 1994, 1995, and 1996.

Research Progress: Best yields were obtained from Alamo switchgrass cut once in early autumn. Alamo switchgrass produced in the range of 8 to 20 Mg/ha of dry matter when cut once at all locations and years except Dallas (and Beeville in 1996).

Task 2. Reduce post-harvest seed dormancy and enhance establishment of switchgrass.

Objective 1: To evaluate dormancy-breaking treatments for freshly harvested switchgrass seed.

Research Progress: Concentrated (16.8 M) sulphuric treatment for 10 minutes allows rapid germination of appreciable numbers of seedlings and eliminates the need for lengthy storage or stratification treatments (Tischler et al., 1994). This technique is useful for plant breeders who deal with small amounts of seed. It is not as useful for producers.

Objective 2: To test the hypothesis that altering seedling morphology in switchgrass to reduce crown node elevation will enhance seedling survival.

Research Progress: Objective 2a: Three cycles of selection for lower crown node placement was effective in lowering the crown node placement of seedlings in greenhouse, growth room, and field seedings. Field tests indicated a significantly higher number of tillers (seedlings) established at each of 3 locations from the low crown selection compared with parental (Alamo) seed (Beeville 76 vs 91; Stephenville 80 vs 100; College Station 31 vs 48 seedlings/2m of row). We have released the selections (lowered and elevated crown node) as germplasm (Tischler et al. 2001) and with more testing may release the low crown as a new cultivar.

Selection for lowered crown node placement affected field grown seedlings in the way we had hypothesized. The crown node was deeper in the soil, resulting in a reduced subcoleoptile internode length. Shoot length was somewhat depressed, as was leaf number; however, the number of secondary roots/plant was increased. Tillering seemed to be somewhat reduced. At Stephenville, the lowered crown node selections had fewer loose seedlings in the field than the unselected Alamo (14 vs 31%). We had observed this phenomena at Beeville, but it rained before we were able to record it. Loose seedlings were seedlings with no seminal roots development at the crown node.

The switchgrass populations were evaluated for response to planting depth in a greenhouse study using soils from Beeville, Stephenville, and College Station plus a commercial potting mix. Seed of selected and unselected lines were planted at 0.5, 1 and 2 cm deep. Treatments were repeated in time. Selected and unselected material was also planted in the field at Beeville, Stephenville, and College Station. Responses recorded include crown depth (placement), subcoleoptile internode length, shoot length, leaf number, and number of nodal (secondary) roots formed. The number of seedlings/tillers per 2 m of row were recorded for two dates at each field location. Percent emergence at day 6 after planting was documented in the greenhouse.

Research Progress: Objective 2b: Selection for lowered crown node (LC) and elevated crown node (EC) did tend to modify mature plant characteristics; but overall, selection for LC (and in some experiments EC) resulted in more desirable mature plant characteristics (increased tillering, enhanced dry matter production and somewhat earlier flowering). In no case did selection for LC or EC result in an undesirable shift in mature plant characteristics. It appears that the observed differences in mature plant characteristics are coincidental shifts not related to phytochrome sensitivity, because the shifts are generally the same direction for both selections.

Elite lines of switchgrass with improved seedling survival were developed. (Elbersen et al. 1998, Elbersen et al. 1999, and Tischler et al. 2001)

Objective 3: To develop switchgrass germplasm with reduced post-harvest seed dormancy.

Research Progress: Some progress was made in selection of a population from Alamo with reduced post-harvest seed dormancy, but further work is needed. Using a similar approach, we have been successful in removing post-harvest seed dormancy in kleingrass, but it took 6 cycles. Due to drought, change of location of seed production and other factors, we completed only 3 cycles of selection in Alamo switchgrass. At least 3 more are needed. (This project was re-started late in the second five years of this project. See 2001 report and ten-year report for update).

Task 3. Enhance management and persistence of switchgrass

Objective 1: To determine switchgrass responses to row spacing and nitrogen and phosphorus fertilizer application in diverse environments.

Research Progress: Alamo switchgrass responded to the first level of P fertilizer (20 lbs P_2O_5/A) in the first year only at Stephenville. At Beeville and Stephenville, the response to N fertilizer was nearly linear to 200 lbs/A in the first two or three years, then quadratic in later years, but there was no evidence of carryover N in the soil at the end of 1996. Soil P analysis indicated a linear accumulation of P in response to increasing rates of P applied at Stephenville and a positive quadratic response at Beeville. The majority of the P accumulation was detected in 0–3" soil samples. The row-spacing effect negatively influenced yields except in 1996 (a drought year) when there was a positive effect. At Beeville, the positive effect in 1996 was on stand persistence. Responses of Alamo switchgrass to N fertilizer levels have been published (Muir et al. 2001). We observed quadratic responses to N and no response to P. Even though the N response was quadratic, the response was still increasing at 200 lb N/Acre (except 1995). In earlier years, there was a negative response or no response to row spacing, but in 1996 there was a positive response to row spacing.

Objective 2: To determine switchgrass responses to timing and frequency of harvest.

Research Progress: The more frequently Alamo switchgrass was defoliated in the summer, the greater the yield reduction. A single harvest in the autumn was always best at Stephenville, but did not hold at Dallas in 1996 (drought year). The best time (September, October, or November) to harvest varied among years and locations (Stephenville vs Dallas) and needs further research. Generally, yields were reduced slightly as the autumn harvest was delayed into November. This is similar to results obtained by David Parrish at VPI, who hypothesized that some of the yield reduction may be due to retranslocation of storage components to roots, and some leaf loss. On the other hand, delaying the final autumn harvest until November had a positive effect on the initial harvest the next spring (Sanderson et al. 1999).

Objective 3: To develop a model of switchgrass development for biomass management.

Research Progress: A computer-driven model for switchgrass yield was developed using a limited data set (Kiniry et al., 1996). The model's simulated yields accounted for 79% of the variability in measured yields. The mean error of prediction was 450 lb/acre. Further refinement, or perhaps a new approach with more parameters, is needed to make the model more robust. Dr. Jim Kiniry, a crop modeler with the USDA-ARS at Temple, used the ALMANAC simulation model to predict Alamo switchgrass yields in Texas (Kiniry et al., 1996). Yield data from 1993 and 1994 were used to test the model. Matt Sanderson and Dale Wolf (VPI) developed empirical relationship of switchgrass morphological development to growing degree days (GDD). Generally, the relationships held within a cultivar and within a location. Similarly, chemical composition was closely related to GDD (Sanderson and Wolf, 1995a,b).

Task 4. Analyze ecophysiological differences of switchgrass ecotypes [NEW TASK in 1996]

Objective 1: To determine if upland ecotypes are more sensitive to nitrogen availability than lowland ecotypes.

Research Progress: Nitrogen increased yields of both upland and lowland ecotypes; however, upland ecotypes had a proportionately greater response to N than did the lowland ecotypes. This research was repeated in 1997 (Jason Stroup 1999, M.S. Thesis).

Objective 2: To determine if lowland ecotypes are more sensitive to soil water deficit than upland ecotypes.

Research Progress: Due to excessive rain (Pot experiment done outdoors), no response to water stress was detected. This research was repeated in 1997 (Jason Stroup 1999, M.S. Thesis).

Additional Research (in addition to originally stated objectives)

Rod Reed, Ph.D. student at Texas Tech University, was near completion of his dissertation research on switchgrass response to sewage sludge and uptake of and tolerance to cadmium. He had completed three greenhouse experiments and two years of field research.

Alternatives to inorganic fertilizers are needed for biomass production to reduce input costs and maintain a positive energy balance. Municipal waste may be an economical source of N and other nutrients. However, response to heavy metals in the sludge is not known.

Research Progress: Switchgrass appears to be tolerant of Cd at low to moderate levels, and little is translocated to the aerial portion of the plant. Municipal sludge should prove useful in the production of biomass from switchgrass with proper management of soil pH. (Reed, 1997. Ph.D. Dissertation).

George Van Esbroeck completed his Ph.D. at Texas A&M University where he completed several field and greenhouse experiments on leaf appearance rate, dry matter partitioning, and day length response in five cultivars of switchgrass with varying flowing time.

Research Progress: Final leaf number of spring-emerging tillers of all cultivars ranged from 9 to 11, whereas summer-emerging tillers flowered after 7 leaves had appeared. A slow rate of leaf appearance was identified as the primary development trait associated with a long duration of vegetative growth of the high-yielding, late-maturing cultivars. (Van Esbroeck. 1996. Ph.D. Dissertation; Van Esbroeck et al. 1997 and 1998).

Table 1.1.1 Alamo switchgrass biomass yield summary of 1992 through 1996, 1-cut and 2-cut system.

	1993	1994	1995	1996
1-Cut				
	- - - - - - - - - - - - - - - Mg/ha - - - - - - - - - - - - - - -			
Beeville	13.6	18.0	7.9	*
College Station	18.8	20.1	19.0	10.5
Dallas	5.2	16.8	5.9	2.6
Stephenville	8.7	19.5	19.8	17.1
Temple	11.4	17.7	17.6	12.6
2-Cut				
Beeville	11.8	16.7	3.0	*
College Station	13.4	19.2	10.9	9.3
Dallas	6.6	12.2	9.9	4.8
Stephenville	*	10.1	13.8	13.3
Temple	10.8	14.2	9.7	4.0

*none taken
1993 yields = 60 lb/A of N fert., all others 120 lb/A N fert.

4. PUBLICATIONS

Refereed Journals

Sanderson, M.A. 1992. Morphological development of switchgrass and kleingrass. Agron. J. 84:415-419.

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5. FIVE-YEAR (1997–2002) PROJECT SUMMARY

ACCOMPLISHMENTS BY TASK 1997–2002

TASK 1: BIOLOGICAL, ECONOMIC AND PHYSICAL CONSTRAINTS TO SWITCHGRASS BIOMASS PRODUCTION.

Objective: The objective of this task was to measure yields from a large enough area to be able to document all input costs as well as any physical problems we may have to deal with in the harvest and movement of large round bales of mature Alamo switchgrass.

A large area was seeded in 1997, but after several failed attempts to improve the stand so production data could be gathered, the decision was made in late 1999 to terminate this project in favor of developing Science-based Best Management Practices need to get a stand of switchgrass.

TASK 2: CHANGES IN SOIL NITROGEN AND SOIL QUALITY ASSOCIATED WITH SWITCHGRASS PRODUCTION

Objectives: 1. Determine the effects of switchgrass production on soil C sequestration, soil microbial biomass C and N , soil C and N dynamics, and particulate organic matter C compared to other forage grasses and cropping/vegetation systems.

2. Utilize the above measurements plus other selected soil properties to estimate effects of switchgrass production on soil quality as compared to other forage grasses and vegetation systems.

Background. Switchgrass has been evaluated over the past 15 years as a possible energy crop, with generally favorable results. Switchgrass also appears to partition considerable C below ground, which could be important for soil C storage, especially with the added emphasis on soil C sequestration as a means of mitigating increasing atmospheric CO_2. Greater knowledge of the short- and long-term effects of switchgrass production on soil biological and chemical properties is needed to assess effects on sustainable land management and the environment. Soil biological parameters are currently being used as indicators of soil quality because these parameters respond more rapidly to changes in soil management than does total soil organic C (SOC). Soil microbial biomass (SMB) and associated activity characteristics have been successfully used as predictors of soil C and N dynamics. SMB is the most active fraction of soil organic matter and may frequently be used to predict changes in soil quality long before the difference can be observed as a change in soil organic matter content. Particulate organic matter (POM) C also represents an active fraction of soil organic matter that has successfully been used to predict longer-term changes in SOC.

1997–2001 Research Results and Discussion. Soil samples under switchgrass, other forage grasses, cultivated cropping systems, and forest were collected annually from 1998 - 2001 at Yoakum, College Station, Stephenville, and Dallas in Texas and at Clinton, Louisiana and Hope, Arkansas. Sampling depths at all locations were 0 to 5, 5 to 15, and 15 to 30 cm. Soil characteristics determined included soil organic C and total N, initial inorganic N, microbial biomass C and N, soil C and N mineralization, basal soil respiration, and particulate organic matter (POM)-C and -N .

Soil organic C (SOC) was greatest under long-term grasses (coastal bermudagrass, bahiagrass/fescue) and forest, intermediate for switchgrass, and lowest for the cultivated treatments. When soil samples for the cultivated wheat/cotton treatment at Dallas were compared with those from Alamo switchgrass planted in 1992, switchgrass planted in 1997, and long-term (~ 30 years) coastal bermudagrass, an additional 30,000, 22,000, and 41,000 kg C per hectare-30 cm were noted for the latter three treatments. When the increase of additional SOC between switchgrass planted in 1992 vs. 1997 was computed, a SOC accretion rate of 1,600 kg C per year to a depth of 30 cm was determined. Comparing SOC in the cultivated wheat/peanut treatment at Stephenville to Alamo switchgrass planted in 1992, switchgrass planted in 1997, and long-term coastal bermudagrass at that location resulted in SOC increases of 11,000, 5,000, and 25,000 kg C per hectare 30 cm, respectively. The annual increase in SOC under switchgrass was estimated to be 1,200 kg C per hectare 30 cm at Stephenville. Smaller increases with switchgrass compared to the cultivated grain sorghum-wheat-soybean treatment were noted at College Station, possibly because of the large residue-C return with this rotation.

Measurements of active fractions of the soil organic matter pool, such as soil microbial biomass C and mineralizable C, were more consistent in trends and absolute amounts within locations across years than was SOC. Various measurements of active fractions and microbial activity were strongly correlated. The fraction of SOC as soil microbial biomass C is frequently used as an indicator of changing soil quality. In this study, the fraction of SOC as POM-C appeared to be a more robust indicator of soil quality and also better correlated with other soil quality attributes. POM-C is more quickly and easily determined than soil microbial C and other longer-term methodologies and, therefore, might be more readily and widely determined. The fraction of SOC as POM-C was either greatest or next to the largest for switchgrass compared to other vegetation treatments across all locations, indicating improvement in soil quality with this treatment.

TASK 3: SWITCHGRASS CULTIVAR AND GERMPLASM EVALUATION

Objectives:

1. **Evaluate both upland and lowland ecotypes from the breeding program at OSU (Dr. Charles Taliaferro) compared to the best upland and best lowland cultivar at Stephenville, Dallas, and College Station, TX; Hope, AR; and Clinton, LA.**
2. **Quantify the long term carbon sequestration trends in all plantings.**

Summary of results from 2001 and evaluation of all previous years data for yield, stand persistence and quality characteristics follows:

Yield, stand characteristics, and composition of switchgrass genotypes across different environments. The variety trial was concluded with three harvest years in Hope, AR, and Dallas, TX, and four harvest years in College Station, TX, Stephenville, TX, and Clinton, LA. Harvested samples from two replications at each site for 1998, 1999, and

2000 were analyzed for acid detergent fiber (ADF), cellulose, lignin, ash, nitrogen, and phosphorus concentration.

Rainfall during the April to September growing period for switchgrass was 17 to 73% below normal at all sites in all harvest years. Average April to September precipitation for sites over the trial period was Clinton, 619 mm; Hope, 478 mm; Dallas, 393 mm; College Station, 371 mm; and Stephenville, 300 mm.

All sites showed differences in dry matter yield (DMY) among ecotype-morphological type groups of entries (Fig. 1). Lowland morphological type entries always had significantly higher DMY than upland type entries. Among upland entries, DMY was highest at the two northernmost sites (Hope and Dallas). At Clinton, upland entries produced harvestable yield only in the first two years of the stand. Within morphological types, southern ecotype was always higher or equal in DMY to northern ecotype. Higher DMY for southern vs. northern ecotype was more often observed within the lowland morphological type than within the upland type, and the magnitude of the improvement was generally larger in years with higher overall yields.

There was evidence that lowland genotypes can be selected for improved yields in particular environments. Yields for individual lowland entries at Clinton, Hope, and College Station are shown in Table 1. In Hope, SL931 ranked at the top of yields and yielded significantly more than Alamo. This entry was also at the top of the yield ranking in College Station, but was not statistically different from Alamo at that site. At Clinton, entry SL941 ranked at the top, yielding significantly more than all other lowland entries except SL931. For lowland entries, the year × entry interaction was significant in Dallas and Stephenville. Lowland entry means for each year are presented in Table 2. In the first harvest year, NL931 yielded less than all other lowland entries in Dallas, and SL932 yielded more than all other lowland entries in Stephenville. In subsequent years, there were no differences in yield among lowland entries in Dallas or Stephenville. It is notable that differences among entries were most likely to be detected at the sites with April to September rainfall over 450 mm (Clinton and Hope).

Over time, average lowland entry DMY increased in Clinton and Hope, remained constant in Dallas, decreased in College Station, and fluctuated in Stephenville. Within sites, cumulative precipitation plus irrigation totals during the growing season were not significantly correlated with lowland entry DMY at Clinton, College Station, or Stephenville. At Clinton, rainfall during May was negatively correlated with lowland entry DMY ® = -0.997, $P < 0.01$), and rainfall during June and July was positively correlated with DMY ® = 0.968, $P < 0.05$ and $r = 0.999$, $P < 0.001$, respectively). At Dallas, cumulative rainfall through May was correlated with lowland entry DMY ® = 0.997, $P < 0.05$), but monthly rainfall was not. At Hope, monthly rainfall during June ® = 0.9999, $P < 0.01$) and cumulative rainfall through July ® = 0.998, $P < 0.05$) were correlated with lowland entry DMY. These results suggest that water availability during May, June, and July was important in determining switchgrass yields in this trial, but that other environmental factors also played important roles.

Stand density at the final harvest is presented in Fig. 2 for Dallas, Hope, Stephenville, and College Station. At Clinton, final stand density was 6.45 and 0 plants m^{-2} for lowland and upland entries. Final stand density was significantly higher for lowland than for upland entries at all sites except College Station. Within upland entries at Stephenville, final stand density was significantly greater for southern than for northern ecotypes. Over time, upland entries thinned more quickly than lowland entries at Dallas, Hope, and Clinton (Fig. 3).

Within the lowland entries in Stephenville, Hope, and Dallas, increased plant size compensated for losses in stand density so that effect on DMY was minor.

There were no significant differences among switchgrass entries for proportion of ADF, cellulose, or P in harvested biomass. There was an entry × site interaction for lignin concentration ($P < 0.01$), an entry × year interaction for N concentration ($P < 0.05$), and an entry × site × year interaction for ash concentration ($P < 0.05$). Upland entries had lower moisture concentration at harvest than lowland entries, but all entries exceeded the desirable moisture concentration for immediate baling at harvest. The site × year interaction was significant for all composition variables. This was likely caused by differences in physiological maturity of forage at harvest in different site-years. Site-year averages for biomass concentrations of DM, ADF, cellulose, lignin, and N are plotted against calendar day at harvest in Fig. 4. Across all site-years, concentration of ADF, cellulose, and lignin increased with date of harvest. Biomass ash, N, and P concentrations were not related to harvest date.

In conclusion, lowland morphological type entries had higher DMY than upland entries in all site-years and had better stand survival at the end of the trial at four out of five sites. Within the lowland entries, SL931 was most frequently ranked near or at the top of yields and was better or equal to Alamo at three sites. At the wettest site, Clinton, SL941 also performed well. Yield differences among entries were greatest at sites with highest rainfall. Rainfall from May to July was most often correlated with DMY. Within the lowland group of entries, composition at harvest was more closely related to date of harvest than to entry. Upland and northern entries tended to be higher in ash than lowland or southern entries.

Table 1. Average dry matter yield of lowland morphological type switchgrass entries harvested once yearly for four years in Clinton, LA, and College Station, TX, and three years in Hope, AR.

	Location				
Entry or year	Clinton	Hope	College Station	Dallas†	Stephenville†
	Dry matter yield, Mg ha^{-1}				
Alamo	10.702 b	16.747 bc	18.707 ab	19.480	10.878
SL931	10.787 ab	19.961 a	20.229 a	19.038	11.285
SL932	10.415 b	18.174 ab	18.008 ab	18.717	13.650
SL941	11.588 a	17.377 abc	16.364 bc	17.291	12.743
NL931	9.304 c	15.118 c	13.415 c	17.685	10.672
NL942	10.648 b	17.272 bc	15.223 bc	18.817	12.189
1998	5.442 g	16.215 e	20.961 e	18.098 d	10.801 f
1999	9.081 f	16.504 e	25.400 d	18.960 d	13.261 d
2000	12.287 e	19.605 d	11.240 f	18.456 d	12.042 e
2001	15.486 d	not harvested	14.288 f	not harvested	11.509 ef
mean	10.574	17.441	16.991	18.504	11.903

abcde Within sites and years, means followed by the same letter are not significantly different (Fisher's protected $LSD_{0.05}$).
defg Within sites, year means followed by the same letter are not significantly different (Fisher's protected $LSD_{0.05}$).
†Significant year × entry interaction ($P < 0.05$) in Dallas and Stephenville.

Table 2. Dry matter yield of lowland morphological type switchgrass entries harvested once yearly in Dallas and Stephenville, TX.

Location	Entry	1998	1999	2000	2001	Entry mean
		Dry matter yield, Mg ha^{-1}				
Dallas	Alamo	19.614 a	20.431 a	18.396 a	not harvested	19.480
	SL931	19.819 a	18.497 a	18.798 a		19.038
	SL932	19.015 a	17.498 a	19.639 a		18.717
	SL941	17.659 a	17.658 a	16.557 a		17.291
	NL931	13.599 b	20.811 a	18.644 a		17.685
	NL942	18.883 a	18.866 a	18.701 a		18.817
Stephenville	Alamo	10.446 bc	12.655 a	10.287 a	10.126 a	10.878
	SL931	10.999 b	13.068 a	8.950 a	12.124 a	11.285
	SL932	13.602 a	14.138 a	12.113 a	14.746 a	13.650
	SL941	11.120 b	14.369 a	14.037 a	11.447 a	12.743
	NL931	8.926 c	12.739 a	11.516 a	9.509 a	10.672
	NL942	9.713 bc	12.596 a	15.349 a	11.101 a	12.189

abcde Within sites and years, means followed by the same letter are not significantly different (Fisher's protected $LSD_{0.05}$).

defg Within sites, year means followed by the same letter are not significantly different (Fisher's protected $LSD_{0.05}$).

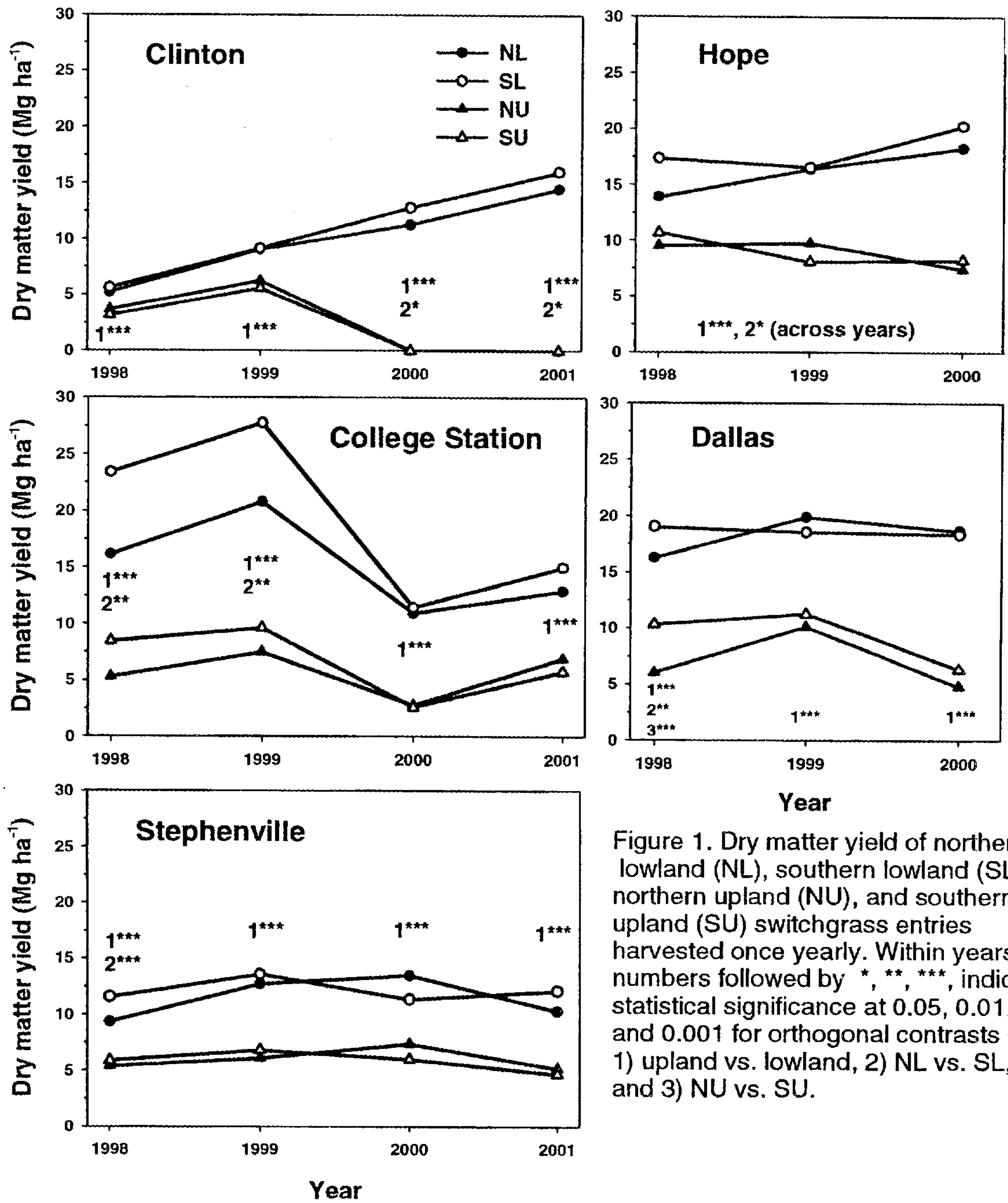

Figure 1. Dry matter yield of northern lowland (NL), southern lowland (SL), northern upland (NU), and southern upland (SU) switchgrass entries harvested once yearly. Within years, numbers followed by *, **, ***, indicate statistical significance at 0.05, 0.01, and 0.001 for orthogonal contrasts of 1) upland vs. lowland, 2) NL vs. SL, and 3) NU vs. SU.

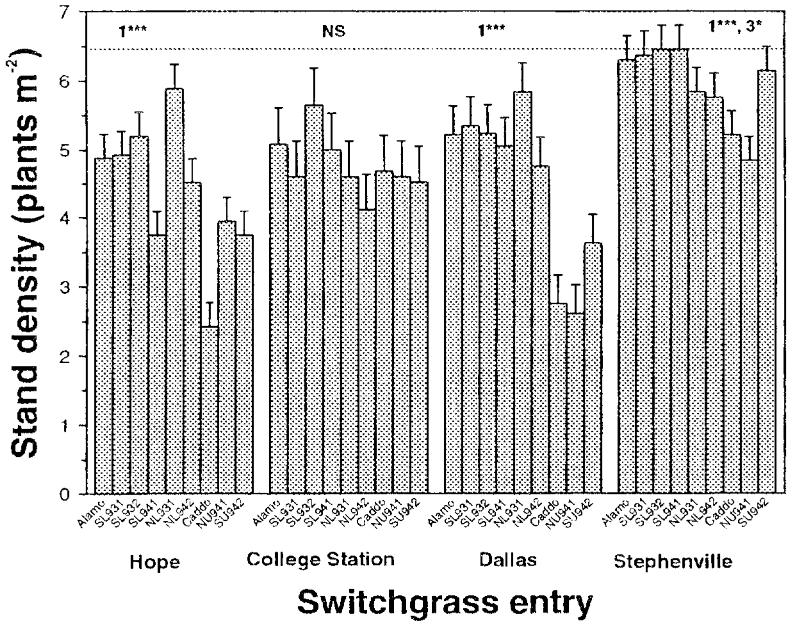

Fig. 2. Final stand density of switchgrass entries after three (Hope, AR; Dallas, TX) or four (College Station and Stephenville, TX) years of annual harvests. The dotted line represents stand density at establishment. Numbers followed by *, **, *** indicate within site statistical differences at the 0.05, 0.01, and 0.001 levels, respectively, for orthogonal contrasts of 1) upland vs. lowland, 2) NL vs. SL, and 3) NU vs. SU.

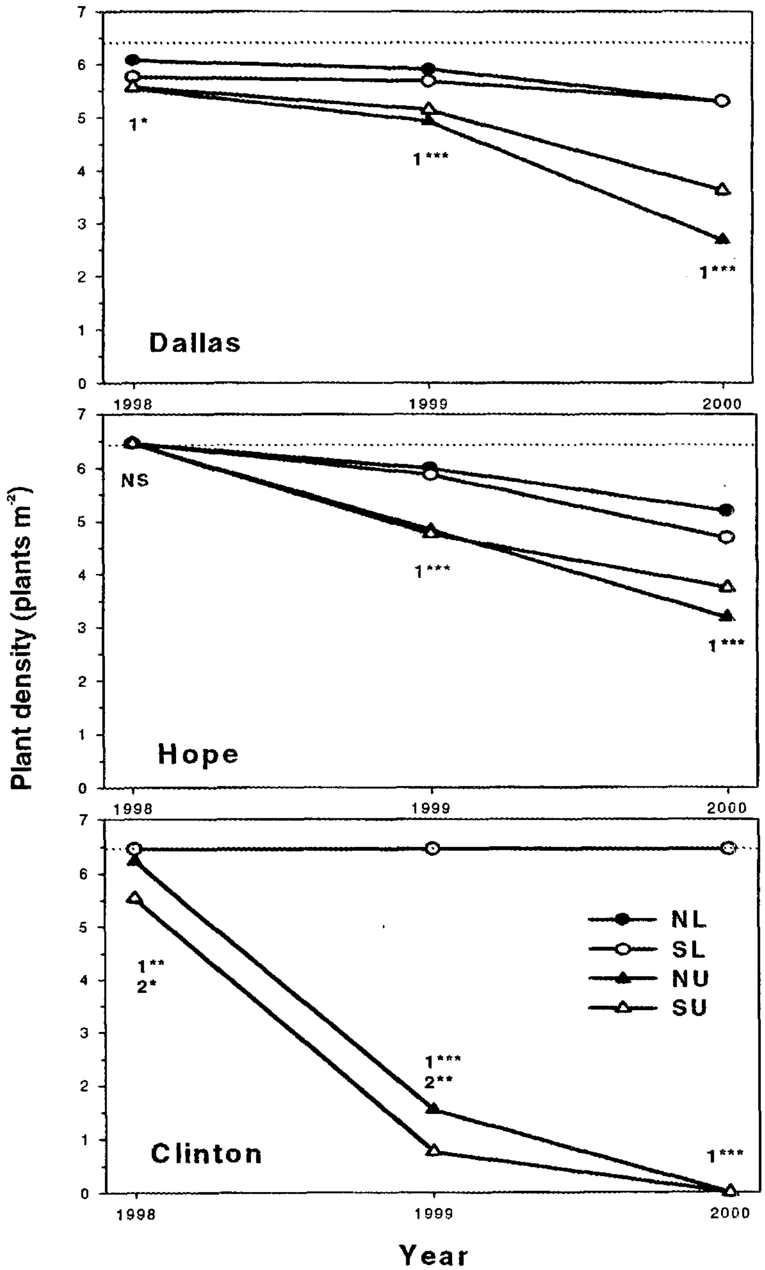

Fig. 3. Stand density of northern lowland (NL), southern lowland (SL), northern upland (NU), and southern upland (SU) groups of switchgrass entries at harvest for three years in Hope, AR, Clinton, LA, and Dallas, TX. The dotted line represents stand density at establishment. Numbers followed by *, **, *** indicate within site statistical differences at the 0.05, 0.01, and 0.001 levels, respectively, for orthogonal contrasts of 1) upland vs. lowland, 2) NL vs. SL, and 3) NU vs. SU.

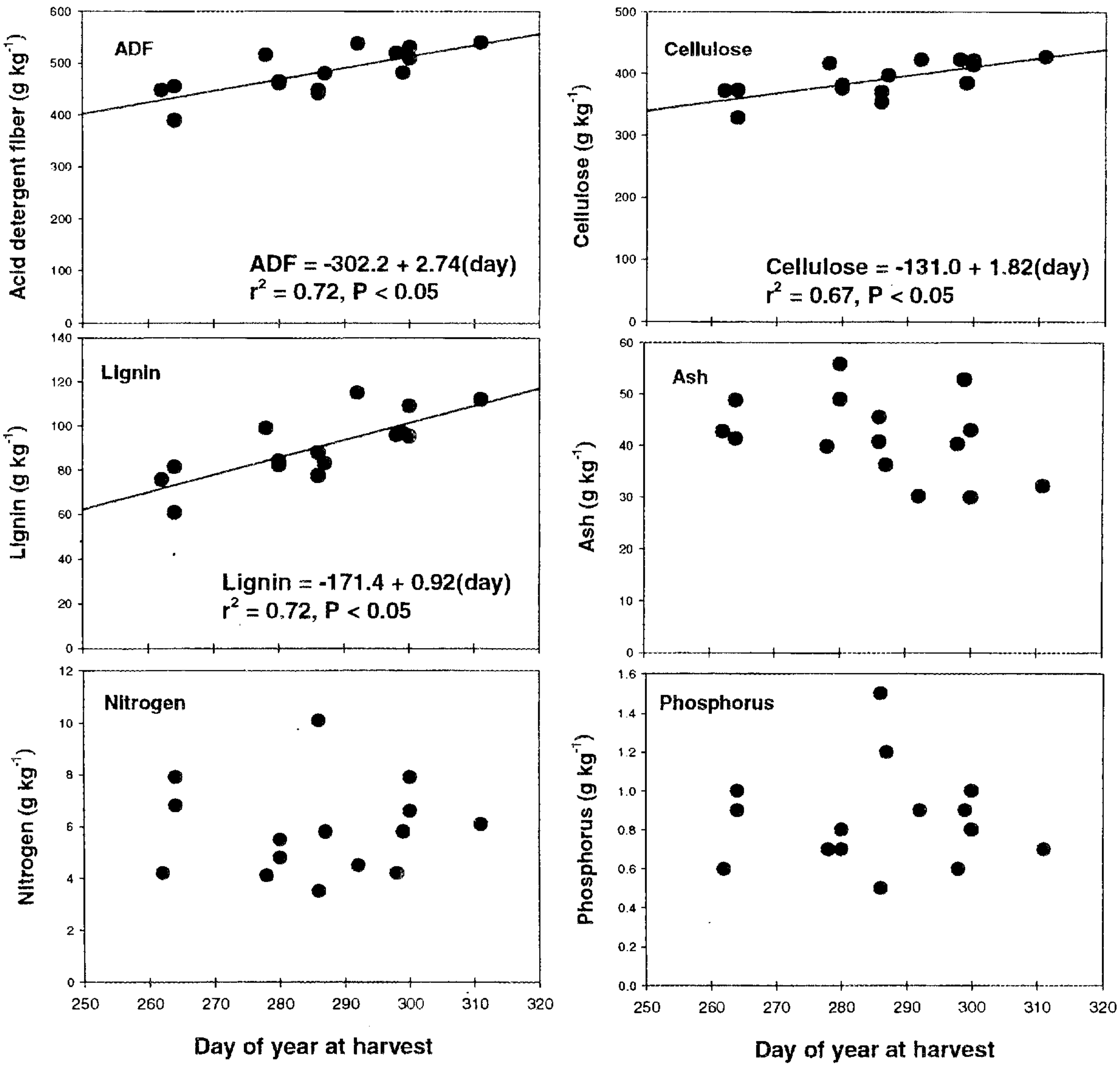

Fig. 4. Relationship of switchgrass acid detergent fiber (ADF), cellulose, lignin, ash, nitrogen, and phosphorus concentration to day of harvest across sites and years.

TASK 4: SWITCHGRASS NITROGEN-PHOSPHOROUS ROW-SPACING STUDY

<u>Original Objectives</u>: Continue evaluation of the experiment established in 1993 to evaluate the long-term effects of an incomplete factorial set of N and P fertilizer treatments in combination with three row-spacings at Stephenville, TX.

<u>Modified Objectives</u>: This task was modified in last year's plan of work. Row spacing treatment was ignored and plots were designed to be harvested across previous row spacings with and without half of each plot to receive the scheduled N rate. {An error was made during the N fertilizer application and the map was incorrectly oriented, so half of the plots did not receive the treatment they were designed to receive.} The data on yield without N applied in 1999 and 2000 is sound, but most of the other data will require some additional work to capture all the results.

This trial, located in ideal bottomland soils, has suffered due to low soil moisture. Fertilizer was not applied to split plots this year so only the residual effects from last year's applications (ignoring row spacing) were measured. First year yields (1999) indicate that there were strong residual effects of N fertilizer (Fig. 4-1) but none from P. The 2000 yields indicate that the residual effects of N are diminishing with time since slope is decreasing and so is total average yield. The later, however, may be an artifact of the cumulative effect of yet another dry summer as well.

1999: R^2=0.81; y=3318+(28.4)x
2000: R^2=0.27; y=3084+(9.8)x

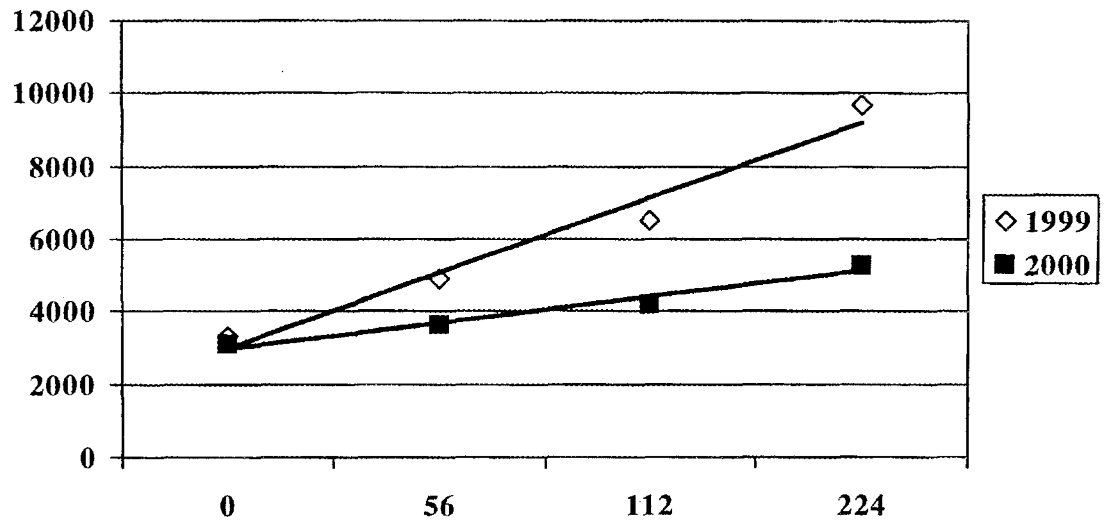

Fig. 4-1. 1999 and 2000 residual effects of N application from 1994-1998.

Selected split plots with no N application last year received 224 kg N/ha. Good stands equate to more stable production over the long run, even with subsequent poor management. However, the lack of N application in the second residual year (2000) shows that the trend is towards yield decline in previously fertilized plots. The inverse is true of previously unfertilized plots that now receive N fertilizer. In 2000, for example, the historically 0/present 244 kg N ha^{-1} yr^{-1} out-produced the historically 168/present 0 kg N ha^{-1} yr^{-1} by 65% (Table 4-1).

Table 4-1. Effect of high N rates on previously unfertilized switchgrass stands.

1993-1998 Treatment	1999-2000 Treatment	1999	2000
--------------------kg N applied ha^{-1} yr^{-1}---------- --------		--kg DM ha^{-1} yr^{-1}—	
0	0	3,089 a*	2,786 a
0	244	5,394 b	8,791 c
168	0	10,315 c	5,332 b
168	244	12,098 d	12,075 d

*Means in the same column followed by different letters differ ($P < 0.05$) according to Duncan's multiple range test.

TASK 5: FACTORS INFLUENCING SWITCHGRASS ESTABLISHMENT

Objectives:

1. **Determine in a series of small plot trials the Best Management Practices necessary to improve the reliability of establishing a stand of switchgrass.**

2. **Conduct controlled environment studies to develop Science-Based knowledge regarding switchgrass stand establishment.**

3. **Select for specific plant traits that are thought to control seedling success.**

Herbicide Screening (Initiated in 1999)

Summary of findings from Herbicide Screening:

Switchgrass is a native North American grass with potential uses in forage production, soil stabilization, and biofuel generation. However, establishment of switchgrass is difficult. Seeds are very small and seedlings are not competitive with weeds that can frequently smother new plantings. Currently, there are no herbicides labeled for use with this crop. Various pre-emergence (PRE) and post-emergence (POST) herbicides were field tested during the 1999-2000 growing seasons to determine switchgrass tolerance. In Arkansas, Atrazine at 2.0 lb ai/A and Caparol at 1.01 lb ai/A applied PRE resulted in $\geq$ 50% stand establishment when rated 9 months after treatment. Switchgrass stands in the untreated check were 6 %. Post emergence herbicides did not affect switchgrass stand scores 4 months after application. Only Pursuit at 0.032 lb ai/A produced higher seedling densities than untreated check. However, 7 month after application Manage and MSMA both at 1.0 lb ai/A had significantly better stands than untreated check. At Overton, methyl bromide provided significantly higher switchgrass seedling density numbers than First Rate or Paramount. Methyl bromide also produced taller switchgrass plants than any herbicide. At Yoakum, First Rate at 0.3 and 0.6 oz/A produced > 70% switchgrass stand establishment while Atrazine at 1.0 lb ai/A produced 50% stand establishment. The untreated check had 40% stand. Switchgrass yields were significantly better than the untreated check with Atrazine at 2.0 lb ai/A and First Rate at 0.6 oz/A.

Overton, TX

The planting date study at Overton, TX with and without Gramoxone applied at planting and the study evaluating different planting practices had thin switchgrass stands because of weed competition. No significant rainfall occurred at Overton from the third week of June until October. All emerging switchgrass seedlings died because of the drought. A weed control study compared a control, hand weeding, methyl bromide, two rates of the herbicides FirstRate and Paramount applied pre-emergence after planting. Methyl bromide is a soil fumigant applied to the soil before planting that kills all weed seed providing a complete weed free seedbed. Herbicide treatments provided some ragweed control but did not control poorjoe, sedges, wooly croton and some other minor weed species. On June 4, two months after planting, switchgrass seedling density was 76.6 seedlings per meter of row with a 60-cm height in the methyl bromide treatment which was greater than the other treatments. Of the remaining treatments, seedling densities ranged from 34.4 to 43.6 seedlings per meter of row with plant heights from 18 to 25-cm with no significant ($P < 0.05$) difference among them. Only switchgrass seedlings in the methyl bromide treatment and about half the seedlings in the hand weeded plots survived the summer drought.

These studies demonstrate the two main problems with switchgrass establishment, slow seedling emergence and weed competition. In the methyl bromide treatment, where weed competition for light, moisture, and nutrients were eliminated, switchgrass seedling density and height were twice that of the other treatments. This demonstrates how vulnerable switchgrass seedlings are to weed competition and there maybe other soil factors influencing switchgrass seedlings. Seedling densities and plant height in the hand weeded treatment, where weeds were removed after switchgrass emergence, were similar to the control. This shows that the harmful effects of weed competition from the rapidly growing weeds, occurs at and soon after switchgrass seedling emergence. Improving switchgrass establishment should be addressed from two aspects, enhanced switchgrass germination, emergence, and seedling growth and controlling weeds.

Another factor that may be affecting switchgrass establishment that has not been studied is soil texture. These studies were planted on a sandy soil that has poor soil moisture retention properties and rapid drying of the soil surface were switchgrass seed is placed. This will be address in a greenhouse study this spring.

Yoakum, TX

Switchgrass herbicide tolerance studies initiated in 1999 were completed in July, 2000. Plots were harvested for dry matter yield estimates. Switchgrass stands were visually estimated at the end of the 1999 growing season (approximately 6 wk after planting) and again after switchgrass had begun growth in the 2000 season.

When rated 6 weeks after planting, the untreated check switchgrass stand established was 40% while First Rate stands establishment was > 70%. Dual Magnum at 0.56 kg/ha, Zorial, Caparol at 1.12 kg/ha, Atrazine at 1.12 kg/ha, Frontier, and Python had stand establishment similar to the untreated check (Table 5-1).

When rated 26 April, after switchgrass had begun growth in the spring, the untreated check had only 2% stand establishment while the high rates of First Rate and Python had 16% stand establishment (Table 5-1).

When switchgrass was harvested for yield, Atrazine at 2.24 kg/ha and First Rate at 42 gr/ha produced the highest yields of > 2200 kg/ha.

A similar study was initiated 17 April, 2000. When stand establishment was visually rated. Strongarm, First Rate at 42 g/ha, and Paramount at 0.28 kg/ha had > 9% stand establishment while the untreated check had 1.8% (Table 5-2). When switchgrass plant height was measured 11 December, all herbicide treatments except Prowl had similar switchgrass heights to the check.

Table 5-1. Response to switchgrass to pre-emergence herbicides at Yoakum TX, seeded 7 Oct. 1999.

Herbicide treatment	Rate kg/ha	--Switchgrass stands-- 11-23-99	4-26-00	DM yield[a] (kg/ha)
		--------- %	---------	
Check	-	40	2	289
Dual Magnum	0.56	28	7	1033
	1.12	8	4	389
Strongarm	0.02	5	1	113
	0.03	0	4	75
Prowl	0.84	15	2	224
Zorial	0.44	45	2	170
Caparol	1.12	28	4	306
	1.68	10	4	347
Cotoran	1.12	13	8	444
	1.68	3	6	426
Atrazine	1.12	50	3	103
	2.24	8	10	2226
Frontier	0.84	43	8	1382
	1.40	20	7	213
Sencor	0.56	13	11	908
	1.12	5	4	137
First Rate[b]	21.0	73	11	1307
	42.0	75	16	3504
Python[b]	35.0	40	12	1691
	70.0	45	16	1556
LSD (0.05)		23	14	1634

[a]Switchgrass harvested 26 July, 2000
[b]grams/ha

Table 5-2. Response to switchgrass to pre-emergence herbicides, at Yoakum, TX seeded in 27 April 2000.

Herbicide treatment	Rate	Switchgrass[a] Stand (29 June)	Switchgrass[a] Height (11 Dec.)
	kg/ha	%	cm
Check	-	1.8	40.6
Dual Magnum	0.56	6.3	45.7
	1.12	3.3	40.6
Strongarm	0.02	20.0	61.0
	0.03	11.0	61.0
Prowl	0.84	0	0
Zorial	0.44	0.3	50.8
Caparol	1.12	1.0	40.6
	1.68	1.0	35.6
Cotoran	1.12	0	25.4
	1.68	0.8	50.8
Atrazine	1.12	0.5	38.1
	2.24	4.0	61.0
Frontier	0.84	4.3	40.6
	1.40	3.8	38.1
First Rate[b]	21.0	5.8	27.9
	42.0	11.3	45.7
Python[b]	35.0	0	25.4
	70.0	0	30.5
Paramount	0.28	9.3	53.3
	0.56	3.8	63.5
Cadre	0.04	2.5	40.6
	0.07	0	27.9
LSD (0.05)		13.1	34.8

[b]grams/ha

2001 Studies. Field studies were completed in the spring of 2002 dealing with switchgrass tolerance to various soil applied herbicides. Switchgrass establishment is a problem in many areas of the southwest due to competition from broadleaf weeds and annual grasses. Establishment may be made easier if competition from these weeds is reduced or eliminated without injury to switchgrass. The use of herbicides can be an important tool that is used to meet this goal.

Material and Methods. A field study was begun in the spring of 2001 in an area with moderate annual grass pressure to evaluate various soil-applied herbicides for switchgrass tolerance. "Alamo" switchgrass was planted 1.3 cm deep on April 27 in a Denhawken fine sandy loam with < 1% organic matter and a pH of 7.2. Preemergence (PRE) herbicides were applied one day after planting (April 28). Herbicides were applied in water with a CO_2 backpack sprayer using Teejet 11002 flat fan nozzles which delivered a spray volume of 190 L/ha at 180 kPa. Visual ratings of switchgrass stands were recorded approximately 6 wk after planting. Plant height measurements were also recorded on the same date. Five plants per plot were selected at random and measurements were made from the ground line to tip of plant growth. Switchgrass was cut for yield on March 13, 2002. Sites were selected at random within a plot and 61 cm x 61 cm areas were hand clipped, dried, and dry weights recorded. Switchgrass yields were then calculated on a per acre basis.

Results and Discussion. The untreated check had approximately 20% switchgrass stand while Dual Magnum at 1.12 kg/ha, Prowl, Zorial, Caparol, Cotoran, Valor at 0.07 kg/ha, Python at 1.0 oz/A and Cadre at 0.07 kg/ha resulted in < 10% switchgrass stand establishment (Table 5-2). First Rate at 0.3 oz/A, Paramount at 0.28 kg/ha, and Atrazine at 1.12 kg/ha plus Paramount at 0.28 kg/ha resulted in > 30% stand establishment.

Little differences were noted in switchgrass plant height when measured approximately 6 wk after planting. Paramount at 0.28 kg/ha treated plots had the tallest plants while Prowl and Cotoran at 1.12 kg/ha showed the least switchgrass growth.

Switchgrass yields were variable due to inconsistent stand establishment (Table 5-3). Dual Magnum at 1.12 kg/ha and Prowl resulted in no harvestable yield while the untreated check, Paramount at 0.28 kg/ha, and atrazine + Paramount mixtures resulted in yields of > 1500 kg/ha dry matter. High yields obtained in the untreated check indicated that weed competition may not be an important factor in switchgrass establishment in areas with low to moderate weed pressure.

Using Activated Carbon as a Herbicide Safener for Switchgrass Establishment

Introduction. The activated carbon technology is common in the grass seed industry in Oregon to aid in establishment and has worked quite well over the years. A greenhouse study was initiated to determine if the concept could possibly aid in switchgrass establishment.

Material and Methods. Herbicides that had shown promise in field studies for weed control and switchgrass establishment were selected for a greenhouse study to evaluate the safening effects of activated carbon when using herbicides on switchgrass seedlings. Switchgrass seeds (100 seed by weight/row) were planted 1.5 cm deep in trays on 27 March. One day later, activated carbon (mixed at rate of 370 kg per 122 L/ha) was sprayed with in a 3.8 cm band over each row of planted switchgrass. Comparison trays were set up without application of carbon strips. Herbicides were mixed and applied with a CO_2 backpack sprayer at 187 L/ha over each tray. Seedling counts (no/15 cm of row) and plant height measurements were taken, 13, 22, 30, and 37 days after planting (DAP). Plants were harvested (15 cm of row) 45 DAP and air dried for 72 hr prior to weighing.

The experimental design was a randomized complete block replicated three times in a factorial arrangement of treatments. Herbicides and carbon/no carbon were factors. An untreated check (w/wo carbon) was included for comparison.

Results and Discussion. Plant numbers in the untreated check varied from 24.0 to 26.3 (with carbon) and 25.0 to 27.7 (without carbon). Switchgrass populations were improved when the activated carbon was used with Paramount, First Rate, or Paramount + Atrazine combinations (Table 5-4). Switchgrass populations were not improved when activated carbon was used in combination with Atrazine alone at either rate.

Table 5-3. Effects of soil applied herbicides on switchgrass stand and growth.

Treatment yield	Rate (kg/ha)	Canopy stand (%)	Plant ht. (cm)	kg/ha
Check	-	21	69.3	3539
Dual Magnum	0.56	20	75.7	535
Dual Magnum	1.12	3	73.7	0
Strongarm	0.02	11	79.8	961
Strongarm	0.03	28	88.1	1301
Prowl	0.84	2	56.9	0
Zorial	0.45	8	81.5	907
Caparol	1.12	7	72.6	1197
Caparol	1.68	7	81.5	383
Cotoran	1.12	3	69.3	610
Cotoran	1.68	5	83.6	427
Atrazine	1.12	15	75.2	580
Atrazine	2.24	19	80.3	1473
Frontier	0.84	19	83.3	851
Frontier	1.40	22	80.0	1325
Valor	0.04	29	84.1	1393
Valor	0.07	9	73.4	863
First Rate	0.02	32	71.4	1128
First Rate	0.04	20	75.2	1366
Python	0.03	20	72.4	1079
Python	0.06	9	77.7	1135
Paramount	0.28	37	96.3	2551
Paramount	0.56	13	80.8	1135
Atrazine + Paramount	1.12 + 0.28	34	91.7	2223
Atrazine + Paramount	1.12 + 0.56	19	83.3	1687
Cadre	0.04	24	83.3	1378
Cadre	0.07	5	78.7	195
LSD (0.05)		29	17.4	2020

Switchgrass plant heights were slightly improved when activated carbon was applied over switchgrass seed without any herbicides. Significant increases in switchgrass plant heights were noted when the activated carbon band was applied prior to the application of all herbicides (Table 5-4).

Switchgrass plant dry weights were not improved when activated carbon was used in combination with Paramount at 0.28 kg/ha, or Atrazine at either rate. Significant increases in plant dry weights were noted with the activated carbon when applied with Paramount at 0.56 kg/ha, First Rate at 0.02 and 0.04 kg/ha, and the combination of Paramount + Atrazine.

These results correlate well with our field studies which have shown a rate response with Paramount and Paramount + Atrazine mixtures. Doubling the rate of these two herbicides resulted in a 55 and 24% reduction in switchgrass forage dry weights in 2001 field studies. Doubling the rate of Atrazine increased switchgrass yield by 250% while increasing the rate of First Rate resulted in virtually no yield increase in our field studies.

Studies in the Midwest have also reported that Atrazine and Paramount are safe on switchgrass. Using activate carbon in combination with herbicides may allow producers to use herbicides which may eliminate severe weed pressure while having no effect on switchgrass. Additional greenhouse and field studies need to be conducted to further study herbicides/activated carbon interactions.

Soil Type and Moisture Level Influence on Alamo Switchgrass Emergence and Seedling Growth

Background. As with most warm-season perennial grasses, switchgrass establishment is difficult because of erratic seed germination and poor seedling growth. Because of poor emergence, weed competition is also a major problem. More risk is associated with establishment on sandy Coastal Plain soils because of their low water holding capacity and rapid drying of the soil surface after a rainfall event. There is no information on how emergence might differ on various soils or what the critical rainfall interval is for seedling survival.

A greenhouse study was conducted to determine the influence of soil series and moisture level on "Alamo" switchgrass emergence and seedling growth. Soils used were Bowie very fine sandy loam and Darco loamy fine sand, which are upland Coastal Plain soils from near Overton in Rusk County. Weswood silt loam is a Brazos River bottom soil collected south of College Station in Burleson County. The Houston Black clay is an upland soil from Temple in Bell County. Soils were put in plastic pots (5 in. wide x 5 in. tall) and placed in the greenhouse. Twelve seed of Alamo switchgrass were placed on the soil surface of each pot and covered with a ½ in. of soil. Pots were watered every 3-4, 7, 10-11, or 14 days. Emergence was recorded daily for the first 28 days and seedlings removed at 6 weeks to compare seedling traits. The study was initiated on March 30, 2001 and repeated on May 29 and July 24.

Table 5-4. Switchgrass seedling response to herbicides with/without an activated carbon applied over the seeded row.

Treatment	Rate	No. Plant/6" row				Plant Ht (cm)			Dry Wt (gr)
	kg/ha	13 DAP	22 DAP	30 DAP	37 DAP	22 DAP	30 DAP	37 DAP	
Check	-								
with carbon	-	24.7	26.0	26.3	24.0	8.2	12.3	19.0	0.680
w/o	-	27.7	25.0	27.3	26.3	7.2	11.0	15.0	0.481
Paramount	0.28								
with carbon		24.7	22.7	24.7	21.7	5.2	6.3	8.7	0.145
w/o		22.3	18.7	20.0	13.0	1.2	1.8	2.2	0.216
Paramount	0.56								
with carbon		23.0	21.7	22.0	17.7	4.5	6.3	10.5	0.477
w/o		24.7	16.0	16.0	5.3	0.8	1.2	1.2	0
Atrazine	1.12								
with carbon		25.0	24.7	24.7	24.0	6.5	8.3	12.5	0.536
w/o		27.0	24.7	25.7	24.0	3.5	4.2	9.3	0.415
Atrazine	2.24								
with carbon		19.7	20.3	21.3	20.0	5.7	10.2	16.3	0.792
w/o		23.7	24.3	25.0	24.7	5.0	8.5	12.2	0.552
First Rate	0.02								
with carbon		29.0	29.7	30.3	28.0	7.0	8.8	15.0	0.720
w/o		26.0	23.7	24.3	22.7	3.7	4.0	5.0	0.211
First Rate	0.04								
with carbon		23.3	24.0	25.0	23.0	6.0	8.3	13.3	0.538
w/o		25.0	23.7	24.3	22.7	3.3	3.8	4.5	0.127
Paramount + Atrazine	0.28 + 1.12								
with carbon		23.3	24.0	24.3	23.7	7.2	11.3	14.7	0.740
w/o		30.0	18.0	17.7	8.0	1.5	2.2	3.2	0.006
Paramount + Atrazine	0.56 + 2.24								
with carbon		22.3	22.7	23.3	22.7	6.8	9.0	16.3	0.650
w/o		25.3	23.0	22.0	18.3	2.5	4.0	4.8	0.183
LSD (0.05)		6.8	7.3	6.9	5.9	1.9	3.8	5.9	0.396

Research Findings. The Bowie very fine sandy loam and the Darco loamy fine sand had similar soil moisture levels. Moisture levels were frequently near 0% at the 10- and 14-day watering intervals with maximum moisture levels of 10 to 15% at the 3-day watering interval. Moisture levels in the Weswood silty loam were never below 5% with maximum levels from 20 to 25% at the 3-day watering interval. The Houston clay had the greatest moisture retention with minimum soil moisture levels at approximately 10% with levels up to 30% for the 3-day watering interval. There were not any consistent differences among soil series for switchgrass emergence. There was a tendency for switchgrass to have greater and more rapid emergence when watered at least every 7 days, especially under the high temperatures during the July 24 run. Seedling survival was always good in the Houston Black clay regardless of watering interval because of its high moisture holding capacity. Seedling survival decreased rapidly in the Darco loamy fine sand and Weswood silty loam when watered only every 10 or 14 days. A watering interval of 7 days or less was necessary for seedling survival of 90% or more in all soils.

The general trend was for seedling development to be more advanced and shoot and root weights to be heavier in the two sandier soils than in the Weswood silt loam and Houston clay soils if the seedlings survived. The Weswood silt loam cracked vary badly, especially at the 10- and 14-day watering interval, which limited seedling growth. Differences in shoot stage among soil types only occurred at the 10- and 14-day watering intervals. Shoot weight differences among soil types were more pronounced than for shoot stage. There was a general decline in shoot weight as the watering interval increased for all runs. Shoot weight differences occurred among soils at each watering interval for every date. The highest shoot weight was in the Darco loam fine sand and lowest in the Weswood and Houston soils.

There was a general decline in root development as watering interval increased. If watered every 3 days, there were no differences among soil series. If the seedlings survived, root stage was more advanced in the sandier soils than in the loam and clay soils. The trends in root weight were identical to that of shoot weight with differences among soil series at every watering interval. As with the other seedling traits, there was a general decline in root weight as watering interval increased, especially at the higher temperatures in the July 24 run. Root weights were always greater in the Darco soil and usually in the Bowie soil if the seedlings survived.

Conclusions. The Darco and Bowie soils are representative of most soils found in East Texas. Switchgrass seedling growth and development was good in these soils, but it was very critical that the seedlings received water every 7 to 10 days. Switchgrass should be planted from late April through mid-May when temperatures are mild and rain chances are good. Necessary rainfall at least every 10 days is one of the factors for unreliable switchgrass establishment on sandy soils in the Lower South. (See 2001 report for details).

Influence of Temperature on Switchgrass Emergence

Background. As with most native warm-season perennial grasses, obtaining good stands is difficult because of small seed size, slow and erratic germination, and poor seedling vigor. Other factors inhibiting switchgrass establishment are seed dormancy and a seedling morphology causing permanent roots to arise from above the seed and near the soil surface. Therefore young seedlings are very vulnerable to drought. Temperature is a major environmental factor that influences seed germination, seedling emergence, and seedling vigor. A growth chamber study was conducted to determine the effect of temperature on switchgrass emergence to identify optimum planting times. Seed of Alamo and Lowdorm, southern ecotypes, and Blackwell, a northern ecotype, were planted in pots and placed in growth chambers set at day/night temperatures set at $68/50^0$, $77/59^0$, and $86/68^0$F. Seedling emergence was recorded daily for 28 days after planting.

Research Findings. Emergence increased as temperature increased but temperature did not affect total emergence by 28 days after planting. By 8 days after planting, seedling emergence in the $86/68^0$F temperature treatment was near maximum emergence and was twice that of the $77/59^0$F treatment. None of the seedlings in the lowest temperature treatment had emerged by this time. The ranking of varieties for emergence rate and total emergence was Lowdorm > Alamo > Blackwell. Lowdorm switchgrass was selected for reduced seed dormancy and it had a greater and more rapid seedling emergence than the other varieties. Maximum emergence was reached at 16 days after planting for the southern ecotypes Lowdorm and Alamo, and at about 24 DAP for the northern ecotype, Blackwell.

Conclusions. In northeast Texas, temperatures from April through October should be adequate for total switchgrass seedling emergence. However emergence would be more rapid if planted in warmer temperatures from May through September if moisture were not limiting. Long term monthly rainfall for May and June exceeds 4 in. so that May should be the optimum switchgrass planting time in this area. The more rapid emergence should also make the switchgrass seedlings more competitive with weeds. Lowdorm switchgrass should be planted in the southeastern USA because of greater and more rapid emergence. (See 2001 report for details)

Selecting for Low Seed Dormancy

Successful production of any crop begins with dependable establishment. Warm-season perennial grasses such as switchgrass are difficult to establish because of small seed size, slow and erratic germination, and poor seedling vigor. "Alamo" switchgrass, a lowland tetraploid switchgrass variety, has demonstrated biomass yield potential sufficient to be considered as a biofuels feedstock in the South and Southeastern United States. However, a major factor limiting widespread planting of Alamo switchgrass is very poor stand establishment from seed. One reason cited for poor establishment of Alamo switchgrass is a stratification requirement that must be met before significant numbers of planted seeds germinate. Because of this stratification requirement, seed often germinate weeks or months after planting, when climatic conditions are not conducive for establishment.

The "stratification requirement" blocking switchgrass germination is probably an oversimplification. The recommended cool, moist prechill converts many seed in a seedlot to a condition where germination may occur, but evidence in the literature suggest that a second obstacle to germination is a requirement for alternating temperatures with approximately a 15° amplitude. Bench-Arnold, et al. (1990, 1998) have demonstrated that Johnsongrass (*Sorghum halapense* Pers.) seed which have been stratified require several cycles of alternating temperature (with an amplitude of approximately 15°C) for germination to initiate. This requirement has been interpreted to be a gap detection mechanism, because this amplitude of diurnal temperature variation occurs only in vegetation gaps, where light competition is minimal, and thus chances for establishment are good.

We have previously greatly reduced post-harvest seed dormancy in Kleingrass (*Panicum coloratum* L.) using recurrent selection (Tischler, et al. 1987). Our objectives in the current experimentation were (1. To use recurrent selection to reduce post-harvest seed dormancy (stratification requirement) in Alamo switchgrass, and (2. To study germination characteristics of seed of individual plants derived from the recurrent selection protocol to determine if germination at alternating temperatures predicts germination response at constant temperature.

Methods and Materials. In the fall of 1992, we collected seed from established Alamo plants at Temple, TX. Within two weeks of collection, we put seed in the germinator (35°C, 25°C) and saved about 150 plants that germinated within two weeks. We transplanted these seedlings into the field at Stephenville TX, in April 1993. We harvested and bulked seed from these plants in October 1993, placed the seed in the germinator as described, and once again saved early germinators as described. Subsequent plants were placed in the field in Temple in 1994. In October 1998 we harvested seed from those plants, put it in the germinator, saved the early germinators and put them in the field at Temple in April of 1999. In the October of 1999, we collected seed from those plants, germinated the seed in the lab at room temperature ( ), and saved early germinators. In March of 2000, 163 of these plants were placed in the field at Temple. In October and November, 2000, seed was harvested from 131 of the most desirable looking switchgrass plants, and placed in the germinator at 35°C 20°C. Germination counts (unreplicated) were totaled for seed from each plant for a period of 28 days. The 24 plants having highest germination were identified, dug from the field, subdivided, and subsequently planted (in four reps) at Temple and College Station TX in April of 2001. Both nurseries were kept well-watered during the summer of 2001. Seed was collected from each of the 24 plants at each location in October and November of 2001, and germination percentages were determined both at alternating (35C-20°C) and constant (30°C) temperatures. For each entry from both locations, germination was determined using four replications of 50 seed each, with reps blocked within a germinator. Analogous bulked control seedlots of unselected Alamo were also harvested both at Temple and College Station to serve as controls for the selected individuals at both locations. Because of variation in maturity dates, only 14 entries were tested in this experiment. These were the first 14 entries where adequate seed had been harvested at both locations for germination testing to be performed. Also, several off-type plants were dropped from the experiment.

Results. Data from the fall 2001 germination experiment is presented in Table 5-5. In all cases (for both location and temperature), germination of seed of each of the 14 genotypes was significantly higher than that of the appropriate control. Germination of the Temple seed at alternating temperatures was especially high, with five of the 14 entries having greater than 90% germination. At alternating temperatures, with only one exception (Entry 44), germination of seed of all Temple clones was greater than that of seed of College Station clones. At constant temperature, germination of seed of all Temple clones was greater than that of seed of all College Station clones. The relationship between germination at constant vs. alternating temperatures differed between locations. The Pearson correlation coefficient for germination at the two temperature regimes for Temple seed was 0.2314 $P = 0.4468$), while for analogous College Station seed the correlation coefficient was 0.9129 ($P < 0.0001$). Although our experiments were not designed to specifically address this issue, the data we collected suggests a strong genotype X location X temperature interaction influencing germination.

Discussion. Panciera (1999) emphasized the fact that industry standards for establishing germination percentage of seed lots are extremely poor predictors of field behavior. By strict definition, germination percentage of switchgrass seed is determined by counting total germination for a period of 28 days in light, with seed moistened with a 0.2% solution of KNO_3 at alternating temperatures of 15 C 30 C. In addition, the seed must have been prechilled 2 weeks at 5C before being placed in the germination environment. As Panciera (1999) indicates, germination percentage indicated on the seed tag includes both readily germinable seed and those whose stratification requirement had been satisfied by the moist prechill. Supplemental (red) light enhances germination of many wild species, and once again in nature is a gap-sensing mechanism (Ballare and Casal 2000). In commercial production, switchgrass seed would be planted in the soil at a depth of approximately 1 cm, where light receipt would be negligible (Woolley and Stoller 1978). Thus, the germination percentage indicated on a seed tag represents the potential maximum germination of that seed lot, a value that has little practical value in the field. As expected, various workers have demonstrated that germination tests in petri dishes over predict emergence in other culture systems (Voigt and Tischler 1997 ; Aiken and Springer, 1995).

Our germination results at alternating vs. constant temperatures support the views of Panciera that germination determinations performed as recommended by ASOSA, while serving as an industry standard, are poor indicators of germination in the field. The requirement for alternating temperatures, while serving as a gap detection mechanism, may inhibit germination during periods of overcast weather—a condition most desirable for germination and establishment in a clean seedbed. It is also obvious because of the lack of a relationship between germination at alternating vs. constant temperatures that the stratification requirement (greatly reduced by our selection protocol) acts independently from the requirement for alternating temperatures for optimum germination (different genes are involved).

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Table 5-5. Germination behavior of seed of 14 clones of Alamo Switchgrass subjected to four cycles of recurrent selection for rapid germination. Temperatures employed were 35°C-20°C (Alternating), and 30°C (Constant). Germination experiments were performed in fall, 2001, within three weeks of seed harvest.

Entry	Temple Seed				College Station Seed			
	Alternating		Constant		Alternating		Constant	
	Percentage germination							
145	98.5	a	56.5	a	47.5	b	42.3	ebdfc
40	94.5	ba	73	a	41.5	b	37	edf
130	93	ba	73.3	a	38	b	41	ebdfc
60	90.5	bac	51.3	a	70.5	a	52.3	ebdac
87	90.5	bac	80.5	a	67.5	a	63.8	a
86	89.5	bc	60.3	a	72	a	54.3	bac
14	88	bc	54.5	a	78.5	a	57.3	ba
93	84	dc	51	a	47	b	37.8	edfc
30	82.5	dc	51.3	a	41.5	b	36.5	ef
114	79	ed	61.8	a	69.5	a	54	bdac
106	77.5	ed	65.5	a	64.5	a	51.5	ebdac
35	77	ed	50.5	a	35	b	28.8	f
44	73.5	e	65.3	a	74.5	a	67.3	a
Control	25	f	16.8	b	8	c	5.5	g

Screening for Seedling Mass

This research was initiated as part of a Ph.D. Dissertation project at College Station, TX. Hector Ramirez initiated this research in early 2000. He has completed the seedling screening on 180 plus single plant seed lots of seed we received from Taliaferro. There is no relationship between seed mass and seedling mass at 2 weeks after emergence ($r^2 = 0.05$). However, the first seedlings to emerge are larger (at 2 weeks after emergence) than the later seedlings that emerge. The heaviest seed-mass seedlings emerge more rapidly (64% by 5 days after planting for the heavy seed mass vs. 50% for the medium and low seed mass groups). The very heaviest seed mass families tend to have some of the heaviest seedlings (at 2 weeks after emergence), so we selected from this group (heavy seed and high seedlings mass) for our effort to enhance seedling establishment traits in switchgrass. The clones that produced these superior seedlings were dug from the field in Stillwater and brought back to College Station and maintained in the greenhouse during the summer of 2000. Out of those 180 genotypes we selected the top 10% (18 genotypes)and we cloned them 7 times to form the first crossing block (18 genotypes X 7 clones = 126 plants). The seed harvested in the fall of 2001 from this first polycross block is the "C1 base."

The graduate student has also screened seed from about 135 Cycle 4 Low-dorm clones maintained at Temple, TX (same seed lots that were evaluated for seed dormancy above). We also selected the top 10% of the plants and cloned them 4 times (15 genotypes X 4 clones = 60 plants). A few of these genotypes (4 or 5 genotypes) matched the selection made from Dr. Tischler (outstanding low dorm genotypes). We are hoping we will get seed from this crossing block in the fall of 2002 and continue with the selection. Seed will be harvested from individual clones from the polycross nurseries.

We just completed growing the seedlings from the base population (C0 base) of switchgrass and the population we made selection for seedling mass from (C1 base). This will allow us to measure the improvement from the original population and the first cycle of selection C0 vs. C1. This was done in a growth chamber with 400 seedlings from every population and we included a check (buffelgrass....apomictic) to measure variability in the growth chamber. This check is needed for publication purposes. We have made selections from seedlings from this trial from C1 plants establish in the field in 2002, so we can set up the next crossing block.

TASK 6: EFFECT OF NITROGEN AND FALL HARVEST MANAGEMENT ON SWITCHGRASS YIELD AND PERSISTENCE

Objectives: The three objectives of this task are to: (1) determine the effect of five N rates and five dates of fall harvest (one harvest per season) on switchgrass biomass yield and stand persistence, (2) determine the effect of N rates and time of fall harvest on switchgrass biomass composition (biofuel quality), and (3) determine the effect of N on the developmental growth rate of switchgrass. This research will be conducted at three locations varying in rainfall and latitude (Dallas and Yoakum, TX and Hope, AR).

Dallas, TX

The Dallas location had three full years of data by early 2001, so we did not impose treatments in 2001, instead, a uniform harvest was taken in the spring of 2001 to try to document carry-over effects.

Plots for this test were used for the clipping frequency test from 1992 to 1996. During 1997, the plots were treated the same so as to eliminate any differences caused by differential harvest the previous years. Treatment design consisted of a 5 by 5 incomplete factorial (nitrogen rate x fall harvest date). Two additional treatment combinations were added so that harvest date 5 received all N rates. Experimental design was a randomized complete block design with two replications. Nitrogen treatments were applied as a single application of ammonium nitrate on April 17, 1998 in 67 kg ha^{-1} increments, from 0 to 268 kg. Ancillary plots and alleys received 134 kg ha^{-1}. Soil analysis performed at the initiation of this experiment indicated a soil pH of 7.9 and no need for the addition of phosphorus and potassium. No herbicides or pesticides were applied during this experiment. Harvest dates were: 10 Aug., 19 Sept., 31 Oct., 11 Dec. 2000, and 23 Jan. 2001.

Effect of Delayed Harvest

In 1998 and 1999, we reported a significant dry matter loss in the range of 27 to 30 kg/ha/day. At Dallas in 2000, the dry matter loss was not significant ($p = 0.24$), but the fitted response showed a loss of 11.5 kg/ha/day. This difference among years we think is due in part to a serious problem we had with rats in the first two years. In 2000, a major effort was made to control the rats at this location.

Response to Applied N Fertilizer

There was a significant ($p < 0.001$) quadratic response to N fertilizer. The formula for the fitted quadratic response is:

Yield in kg/ha = $4223 + 86.26x - 0.239x^2$ Where x = kg of N fertilizer.

Both x and x^2 are highly significant ($P < 0.0001$)

This fitted response gives a maximum yield response (of near 12,000 kg/ha of DM) with about 165 kg/ha of N fertilizer, which is somewhat lower than the 211 projected for 1998, but right on with the 165 that was projected for 1999. Since the fit is quadratic, the economical optimum is likely somewhere in the 120 to 140 kg/ha range.

Hope, AR

Data collection on this task was suspended at Hope in 1999 while we attempted to improve plot uniformity. This was successful, and plots were uniform and healthy for 2000. We redesigned the treatments to allow for a larger plot size in accordance with border effects observed at other sites. In 2000, we had two replications of three target clipping dates (August, late October, and January), and four N fertilization rates (0, 75, 150, 225 lb N/acre) laid out as a split plot with N rate as the main plot. In 2000, we sprayed plots with 0.1 oz/acre of Ally on February 29 to control broadleaf weeds, hand-weeded to control vetch, applied 60 lb/acre of P_2O_5 and 120 lb/acre of K_2O in February, and applied nitrogen treatments on April 21. In 2001, no weed control was needed, and we applied 60 lb/acre of P_2O_5, 120 lb/acre of K_2O, and nitrogen treatments on 26 April.

In 2000, analysis of variance revealed no differences in dry matter yield (DMY) across nitrogen rates or harvest dates (Table 6-1), nor was DMY related to N rate or harvest date in regression analysis. Biomass harvested in January was completely cured and thus drier at harvest than biomass harvested in August or October ($P < 0.001$).

Table 6-1. Yield, dry matter at harvest, and lodging at harvest for Alamo switchgrass fertilized at four rates of nitrogen and harvested on three dates at Hope, Arkansas.

Harvest date	N rate (kg/ha)	Harvest DM (%)	DMY (kg/ha)	Lodging (%)
Aug 28, 2000	0	56.1	15713	10
	84	57.3	18638	55
	168	53.4	17275	60
	252	56.4	17294	73
Oct 31, 2000	0	56.5	17497	0
	84	57.8	19813	55
	168	59.5	20041	45
	252	56.9	18816	53
Jan 26, 2001	0	89.1	14977	15
	84	88.3	18682	40
	168	87.2	16685	75
	252	86.6	15995	80
Probability levels				
Nitrogen rate		ns	ns	0.06
Harvest date		0.0001	ns	0.02
rate * date		ns	ns	0.05

The most obvious difference among treatments was in percentage of stand lodged at harvest time. Across N rates, lodging was greater in August and January than in October (49.4, 38.1, 52.5, respectively). The decrease in lodging in October was likely a result of new growth that was observed after drought-breaking rains in September and October. By analysis of variance, lodging score differed across N rates only in January ($P < 0.01$). However, by regression analysis (Table 6-2), N rate was related to lodging score in August and January ($P < 0.05$) and tended to be related in October ($P < 0.08$). Within harvest dates, DMY was not significantly related to lodging score. However, overall, switchgrass DMY was quadratically related to lodging score at harvest. Regression equations for relationships observed in 2000 are:

Table 6-2. Regression equations relating switchgrass dry matter yield (DMY, in kg/ha), lodging score at harvest (L, as % of stand area), and nitrogen fertilization rate (NR, in kg/ha).

August	$L = 12.4 + 0.52(NR) - 0.001(NR^2)$, $r^2 = 0.66$, $P < 0.05$
October	$L = 4.1 + 0.60(NR) - 0.002(NR^2)$, $r^2 = 0.65$, $P < 0.08$
January	$L = 13.0 + 0.45(NR) - 0.0007(NR^2)$, $r^2 = 0.92$, $P < 0.01$

overall $DMY = 16237 + 149(L) - 1.9(L^2)$, $r^2 = 0.23$, $P < 0.06$

In 2001, nitrogen rate again did not affect DMY; however, harvest date did with the following relationship:

DMY (kg/ha) $= 7976 + 141.92x - 0.46x^2$, $r^2 = 0.81$, $P < 0.001$, where x is day after August 1.

Forage was drier at each successive harvest in 2001. Lodging of stands was greater in 2001 than in 2000. Lodging was not affected by harvest date in 2001, but it was affected by N rate. Overall, lodging was not related to DMY in this year.

A large part of the absence of a DMY response to N at Hope versus the other sites is attributed to the lodging problem, which was greater at higher rates of N. Lodging probably contributed to decay of material that fell to the ground prior to harvest, and lodging in 2000 likely also to thinning of stands that continued to influence yields in subsequent years.

Yoakum, TX

Yoakum is located in Lavaca County in the land resource area known as the Texas Blackland Prairie. This site was planted on Sept. 16, 1997. The site was drilled in using 20-in row spacing and 5 lbs of seed/A (4 lbs PLS). This is a sandy site [Strabor loamy sand (fine, mixed, thermic Aquic Paleustalfs)] and was approximately 113 ft by 200 ft. On Oct. 25, 1997, 340 lbs/A of 13-13-13 was applied to stimulate growth and development. The stand came out of the winter of 1997-98 in good shape.

N fertilizer (Urea) was applied in late March of 1999 and early April of 2000 and 2001 at 5 rates similar to the Dallas site.

In 1999, the site at Yoakum was burned on February 3 to remove previous year's growth. Weeds were sprayed with 1 qt/A of Grazon P+D on February 23. Plot harvesting was done at about 6-week intervals starting on August 18, 1999, as per the protocol.

The response to N and delayed harvest showed no interaction in any year, so we will report each factor separately for ease of comparison.

Effect of Delayed Harvest

For 1999-2000, the linear fit to daily dry matter loss was significant at $P = 0.036$, and the loss was 14.7 kg/ha/day. For the 2000-2001, the fit again was linear but not significant ($P = 0.219$), and the loss of dry matter was 9.4 kg/ha/day.

In 2000-2001, the quadratic fit was a bit better, indicating that the tail end of the season (January and February) losses were more significant than the earlier part of the season (there was actually a net increase in dry matter through the third harvest). The fitted quadratic formula for the 2000-2001 season was slightly improved over the linear fit ($P = 0.097$) and the formula was:

Yield after August 1, 2000 = $8908 + 52.42x - 0.27x^2$, where x = days after August 1

Response to Applied N Fertilizer

The response to N-fertilizer was best described by a quadratic fitted statistic in 1999 and 2000, and by a linear statistic in 2001. The fitted formulas are:

Yield response to N in 1999 = $5919 + 53.10x - 0.13x^2$, where x = kg N applied

Yield response to N in 2000 = $6105 + 55.39x - 0.13x^2$, where x = kg N applied

Yield response to N in 2001 = $7271 + 20.69x$, where x = kg N applied

The response to added N was amazingly close in the first two years. For these years, the fitted quadratic response is amazingly flat, with the maximum yield close to 200 kg of applied N, but the response to the last 50 to 70 kg of N are real marginal. The response to added fertilizer was less in the third year than in prior years and the average yield was lower. So like the Dallas location, the economical optimum will likely be in the 120 to 140 kg of applied N range.

Forage Composition

In early 2002 we completed forage analysis for the following site-years: Dallas-2000, Yoakum 1999 and 2000, and Hope 2000. In Hope and Dallas, proportion of acid detergent fiber (ADF) increased linearly with harvest date, but was not significantly affected by N rate. Lignin concentration was not affected by treatment in Hope or Dallas. In Yoakum, ADF increased linearly with harvest date in both years, while lignin increased linearly in 1999 and quadratically in 2000. In both Hope and Dallas, proportion of N in harvested samples increased with N rate and was not affected by harvest date. Conversely, in Yoakum, N concentration decreased linearly with harvest date in 1999 and was not related to N rate in either year. Equations are shown below.

Hope 2000 ADF (g/kg) = 45.74 + 0.05x, $P < 0.001$, where x = days from August 1

N (mg/kg) = 4616.33 + 13.27x, $P < 0.001$, where x = kg N applied

Dallas 2000 ADF (g/kg) = 42.01 + 0.05x, $P < 0.001$, where x = days from August 1

N (mg/kg) = 4088.67 +13.52x, $P < 0.001$, where x = kg N applied

Yoakum (where x = days from August 1 for all)

1999 ADF (g/kg) = 43.18 + 0.04 x, $P < 0.001$

2000 ADF (g/kg) = 44.20 + 0.06x, $P < 0.001$

1999 Lignin (g/kg) = 0.64 + 0.0022x, $P < 0.001$

2000 Lignin (g/kg) = $0.71 + 0.0075x - 0.000029x^2$, $P < 0.001$

1999 N (mg/kg) = 5480.78 - 7.4020x, $P < 0.001$

Across sites, equations relating ADF concentration to harvest date are similar. The response of N concentration to N rate was also similar where a significant effect was found.

Carry-over Effects

The Dallas location had three full years of data by early 2001, so we did not impose treatments in 2001, instead, a uniform harvest was taken in the spring of 2001 to try to document carry-over effects. These results will be combined with the similar harvest taken at Hope and Yoakum in the spring of 2002 and analyzed for carry-over effects. Until then we have insufficient data to draw a conclusion.

TASK 7: **CUTTING HEIGHT AND FREQUENCY** (Not funded)

TASK 8: **SPACIAL VARIABILITY OF SWITCHGRASS BIOMASS PRODUCTION**

We attempted to establish a large block of Alamo switchgrass in an old pasture at College Station, but never got enough of a uniform stand to attempt to measure variability due to soil characteristics. We had serious problems with Johnsongrass, and multiple attempts to thicken the stand with reseeding treatments all failed. This is another experiment that was terminated in late 1999 in favor of spending more effort develop Science-based Best Management Practices for establishing switchgrass.

Task 9: **ALTERNATE SPECIES** (NEW in 2000)

Objectives: **Since Switchgrass stands cannot be maintained at the southern locations in Texas, we will evaluate alternative species for their potential as a biomass crop. The two plants that we have agreed to evaluate are Bundleflower, *Desmanthus bicornutus* and native shrubby legume that is native to Mexico and Southern Texas, and Giant Reed, *Arundo donax*, a C-3 perennial that is found along the roadsides all over the eastern half of Texas.**

<u>LEGUMES:</u> We planted 3 of the 4 native shrubby legumes that we have under evaluation in South Texas for forage at two locations (Beeville and Yoakum). These lines (BEDES-06, BEDES-37 and BEDES-57) are native to Mexico and the Southern USA. We originally selected these lines for their have excellent seedling vigor and drought tolerance, and they are well adapted to the calcareous soils of the region. We have determined from previous evaluations that they are well adapted to South Texas, but have not determined their yield potential for biomass. These legume are currently under evaluation for use as a wildlife food and cover plant. Preliminary data on its use as a wildlife plant are outstanding. For wildlife utilization, we have found that relatively low plant populations are adequate. These legumes should require no N-fertilizer. We have not determined the P_2O_5 requirement, so we will also evaluate P_2O_5-fertilizer rates. We established the same experiment at two locations using 3, 10 and 20 lb/ac of seed. The experiment was established in a factorial designs to evaluate plant density and P_2O_5-fertilizer responses in the same experiments.

On May 1, 2000, we seeded 4 replications of 3 genotypes, and seeded each at 3 seeding rates (3, 10 and 20 lb/A of scarified and inoculated seed) at TAES-Beeville. The plan also called for a response to P-fertilizer rates, but those were not applied in 2000. These plots were irrigated as needed in 2000, as we received limited rain in the summer of 2000. We applied Pursuit and Fusilade to control the weeds. The plots were harvested on Dec. 8, 2000. December is too late to effectively harvest this plant, as leaf and seed shatter was in an advanced stage, but yields were in the 3000 to 5000 lb/A range, with the later maturing lines providing the highest yields. In 2001, 3 rates of P_2O_5 (0, 40 and 80 lb/A) were applied on May 8, 2001. No supplemental irrigation and no herbicides were used in 2001.

All plots were harvested for biomass yield on Oct. 29, 2001. There were no significant interactions and P-rate was not significant. There was a significant seeding rate effect as well as a difference among the 3 lines for yield. The mean dry matter yield of the seeding rates was as follows: 3 lb-rate = 6883 lb/A, and it was significantly better than the 10 and 20 lb-rates which were not different and were 6143 and 6109 lb/A, respectively. The 3 experimental lines are designated BEDES-06, BEDES-37, and BEDES-57, and the smaller the number the later the maturity (just coincidental). The observed mean dry matter yields were 7315, 6159 and 5515 lb/A for lines -06, -37, and -57, respectively and each was significantly different. These are respectable yields considering almost no rain from May through August. In addition, this is a native shrubby legume that was under development for both grazing and wildlife use, so the potential to add this legume to switchgrass based systems may prove useful as a N source as well as benefit wildlife. These lines of *Desmanthus* grow to about the same height at switchgrass and fix a fair amount of N from the air, thus *Desmanthus* might be a plant that could be grown in association with switchgrass in a no or low N-fertilizer input system to contribute to a lower cost biomass production system.

GIANT REED: Giant reed (*Arundo donax*) grows throughout the eastern half of Texas, and is also known to grow in California, and much of the Southeast (David Bransby is evaluating it in Alabama). It appears to have tremendous potential as a biomass crop in Texas. This giant reed can be found along the highway right-a-ways in Texas down to the 20 to 25 inch rainfall areas and it extends further south and west than we have been able to grow switchgrass. It does not seem to spread except by intentional planting.

We obtained yields (Table 9-1) from an existing stand at a site near Halletsville, TX in 2000. The area was harvested off in the spring, and 0, 50 and 100 lbs of N/A were applied. In the fall of 2000 we harvested these plots. Our conclusion in 2000 was that with yields in this very dry year that exceeded 20 Mg/Ha of dry matter that it may be worth pursuing this crop more seriously in Texas.

Table 9-1. Giant Reed fertility study at Hallettsville, TX

Treatment	Giant Reed Fresh wt	 Dry wt
	Lbs/A	
1. Check (no N applied)	17,545	9,680
2. 50 lb N per Acre	35,090	21,780
3. 100 lb N per Acre	36,300	21,780
LSD (0.05)	NS	NS

The giant reed responded to fertilizer although there was no significant difference between 50 and 100 lbs. of N per acre.

Giant Reed was established at TAES-Beeville on March 2 and 3 of 2000. Four blocks (each 85 by 22 feet) were planted using mature canes laid 3 or 4 wide overlapping in trenches about 3 to 5 inches deep. The trenches were 36 inches apart. The area was irrigated as needed throughout the 2000 growing season. On April 4, 2000 the entire area was sprayed with 1 quart per acre of 2,4-D. That application of 2,4-D did control the broadleaf weeds we had, but was also quite detrimental to the Reed, especially on rep 2. On May 18, 2000, 100 lb/A of N as urea was applied uniformly to the entire area. The growth from 2000 was not removed. On May 1, 2001, N fertilizer treatments were applied in 15-foot wide strips across each rep (Rep 2 was still had a fairly weak stand at the time we put on the N-fertilizer). Rates of N were 0, 40, 80, 120, and 160 lb N per acre as urea. We received very limited rainfall after fertilizing the plots until late August. Plots were harvested on 1-22-02 and 1-23-02, using a sickle bar cutter. A 6 foot 11 inch area was cut in the middle of each plot, the entire length of the plot (21 foot). Plots were cut to a 5 inch stubble. Samples of several canes from each plot were chopped in a hammermill to facilitate drying. Dry matter yields were determined and the data analyzed via SAS. There was no N-response (p = 0.94) and the mean yield over the 3 N-treatments was 9082 lb/A with Rep 2 left out, or 8298 lb/A with Rep 2 included (Rep 2 was severely damaged with the 2,4-D treatment in 2001, and had a lower stem density). The lack of N-response has been reported before for this crop (last year we reported a response to only the first 50 lb of N on an established stand near Halletsville, TX) , but it may also have something to do with that fact that we received limited rainfall for nearly 4 months after we applied the N fertilizer and Halletsville normally gets nearly 30% more rain than we get at Beeville. The 2001 yields are comparable to the 2000 yields from plots with no added N.

The bigger issue with Giant Reed is that it apparently is not very wildlife friendly, and is perceived as a weed by many. So in spite of its yield potential, it is unlikely that we will want to promote it as a biofuel crop. -

TASK 10: IRRIGATION RESPONSIVENESS OF ESTABLISHED ALAMO SWITCHGRASS (NEW IN 2000)

Objective: **The objective of this task will be to evaluate the potential response to targeted irrigation on land that is considered prime switchgrass growing land. We compared non-irrigated with 2 irrigations in mid summer. The N-rate was intended to be high enough that N was not limiting.**

This task was established at College Station in the spring and summer of 2000. The first attempt was by direct seeding, which was a failure. Therefore, several thousand seedlings were started in the greenhouse and transplanted into an adjacent area in June of 2000. The planting configuration was 36 inch rows with plants space 1 foot apart in the row. The entire area was fertilized with 150 lb/A of N on Apr. 17, 2001. We had a wet spring at College Station (see rainfall summary tables at the end of this section), so irrigation was not applied until July 23 and then again on August 10. The rainfall record show that College Station received over 8 inches of rain in August, but it came in the last 2 or 3 days of the month. On Sept. 21, 2001, 6 rows 200 feet long were harvested in the irrigated block and 6 rows 200 feet long were harvested from the non-irrigated block. The dry matter yield from the non-irrigated block was 17,657 Kg/Ha, while the irrigated block produced 23,288 Kg/Ha. Due to layout of the irrigation system, replication was not possible, so there is no way to statistically analyze the data. However, this does support other irrigation observations we have made, and does support the data gleaned from the Variety Trials conducted over 18 location-years, that water (rainfall) in the May through July period accounts for most of the variability in annual yields.

TASK 11. CROP RESIDUES (NEW IN 2000)

Objective: The objective is to document stubble yields from corn and sorghum crops grown at multiple locations in Texas and compare them to the grain yields on the same plots.

Alternate biofuel sources to supply a biofuel conversion plant would include the biomass that is produced in corn and sorghum production in years when there is a (corn or sorghum) crop failure. It is anticipated that in drought years, corn, and to a lesser extent sorghum, that is traditionally planted for grain will have an opportunity to be used for fuel, as partial to complete crop failures are common in much of Texas. These corn/sorghum crop failures will also likely coincide with periods when dedicated biofuel production will be depressed. We collected stubble yield data on existing non-irrigated plantings to document available biomass in corn and sorghum variety trials. This data was collected from ongoing research supported in part by regional corn and sorghum variety trials. Table 11-1 provides the grain and stubble yields for 4 locations each in 2000 on the same variety of corn and sorghum. Residue or stubble yields of sorghum are about equal to or greater than the corresponding grain yields. However, for corn, the grain yields can be about 2X that of the stubble depending on location. Yields of stubble in general were in the 2 to 3 ton range.

Table 11-1. The following data were provided by Dennis Pietsch and the Texas A&M Univeristy crop testing program. All sites are dryland. The stover represents the harvest of 2 replications in the summer of 2000.

	Yield (kg/ha)	
	Corn-Pioneer 3223	
Location	Residue	Grain
Corpus Christi	4,452	4,553
Wharton	5,648	10,311
Granger	5,324	7,000
Prosper	3,803	7,808
	Sorghum-ATx378 x RTx430	
Gregory	6,250	4,673
Danevang	6,221	7,576
Granger	8,183	6,316
Prosper	6,580	6,411

Table 11-2 provides the grain and stubble yields for 2 locations of corn and sorghum in 2001. The 2001 data suggests that corn residue will likely not provide sufficient yield in Texas to warrant the harvest. However, Grain Sorghum residue at least at the Granger location appears to be more promising in terms of yield per acre to justify harvest.

Table 11-2. Corn and Grain Sorghum residue and grain yields at Granger and Prosper, TX in 2001.

Location	Crop	Variety	Residue Yield	Grain Yield
Granger	Corn	DK 689	2960 lb/A	115.7 bu/A
Granger	Corn	Pioneer 3223	2030 lb/A	130.7 bu/A
Prosper	Corn	DK 697	1270 lb/A	51.9 bu/A
Prosper	Corn	31 B13	1065 lb/A	61.4 bu/A
Granger	G. Sorghum	DK 54	6924 lb/A	8288 lbs/A
Prosper	G. Sorghum	DK 54	2474 lb/ A	4530 lb/A
Prosper	G. Sorghum	ATx378xRTx430	2385 lb/A	3442 lb/A
Granger	G. Sorghum	ATx378xRTx430	6009 lb/A	6586 lb/A

The above data were provided by Dennis Pietsch and the Texas A&M University crop testing program. All sites are dryland. The stover (residue) represents the harvest of 2 replications in September of 2001. Granger is located due west of College Station and due south of Temple. Prosper is located north of Dallas.

Table 11-3. Rainfall Table

Monthly rainfall (inches) for 1992-2001 and long-term mean rainfall for Beeville, College Station, Dallas, and Stephenville, TX; monthly rainfall for 1997-2001 and long-term mean rainfall for Yoakum, TX; Hope, AR; Overton, TX; and Clinton, LA.

Beeville, TX

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1992	4.05	5.69	2.10	8.85	7.38	2.36	2.42	4.06	5.30	2.20	2.48	1.24	48.13
1993	1.57	2.42	5.01	1.92	8.16	7.84	.07	1.25	.92	2.03	.59	5.77	37.55
1994	1.53	1.15	5.20	1.67	5.11	3.32	.41	2.99	5.66	6.97	.28	2.01	36.30
1995	.47	.57	2.11	1.87	1.34	2.48	2.31	2.48	1.93	1.18	2.02	1.61	20.37
1996	.01	.09	.25	.21	.00	4.57	.03	6.61	6.45	1.20	.99	.99	21.40
1997	1.19	1.25	5.27	6.01	4.73	5.54	.32	.67	2.26	10.27	2.14	.88	40.53
1998	1.16	4.69	2.43	.94	.00	.27	1.32	5.62	5.23	7.82	4.91	.75	35.14
1999	.50	2.44	2.36	4.42	1.32	4.09	3.61	2.35	.86	1.07	.15	.55	23.72
2000	2.54	.54	4.32	.90	4.51	6.73	.37	.26	.72	3.41	5.63	1.30	31.25
2001	2.45	.18	3.42	.00	1.28	1.56	1.94	10.34	9.06	.92	4.85	2.56	38.56
Mean*	1.80	1.80	1.82	2.49	3.67	3.40	2.50	2.44	4.06	2.88	1.98	2.11	30.95

College Station, TX

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1992	4.92	9.82	1.00	4.20	10.30	6.40	.87	.49	.83	3.50	4.80	4.41	49.77
1993	6.00	1.98	4.61	3.86	7.26	11.12	.00	.08	1.95	4.96	3.03	2.39	47.24
1994	2.38	2.69	2.28	1.74	5.48	3.66	.11	5.01	3.75	18.77	.86	10.72	57.44
1995	3.26	1.13	3.26	4.20	7.46	2.92	3.65	1.02	5.54	1.54	2.42	4.64	41.04
1996	.26	.36	.95	4.74	.63	2.32	1.87	10.32	1.61	1.66	3.62	1.65	29.99
1997	2.88	3.96	3.36	4.01	3.68	6.66	.94	.78	3.66	4.87	4.22	2.86	42.17
1998	3.81	5.23	2.43	1.17	.11	Trace	Trace	.73	3.83	8.84	6.57	4.82	37.54
1999	.05	.16	3.64	2.57	4.15	4.85	2.38	.77	.73	1.57	1.10	1.53	24.40
2000	3.14	.67	2.56	2.00	5.59	2.54	.00	.22	1.51	3.47	9.73	3.79	35.52
2001	2.45	1.57	6.18	.24	4.80	6.30	1.69	3.49	8.75	3.52	2.87	3.54	45.40
Mean	2.65	2.65	2.58	3.38	4.80	3.68	2.29	2.42	4.87	3.81	3.15	2.83	39.08

Dallas, TX

1992	3.08	2.14	3.37	1.80	9.22	5.05	2.56	1.32	1.19	4.27	3.12	4.43	41.55
1993	2.04	6.58	1.98	4.54	2.58	4.32	.00	2.85	4.33	6.10	3.28	2.53	41.13
1994	1.74	2.40	1.51	3.45	6.08	1.98	7.37	6.14	4.60	10.30	7.50	2.53	55.60
1995	2.79	.82	7.95	4.85	7.74	1.72	3.75	1.81	1.60	1.13	.07	2.14	36.37
1996	1.54	1.03	1.99	2.09	1.67	2.51	3.21	4.21	1.87	13.38	6.20	1.04	40.74
1997	.55	7.90	2.80	7.22	5.57	4.26	.88	3.41	.49	5.32	2.00	7.83	48.23
1998	6.15	4.18	4.17	1.46	2.44	2.04	.37	.01	3.21	7.72	5.21	6.82	43.79
1999	2.20	.89	2.61	2.51	7.61	3.26	1.86	.00	1.14	2.85	2.62	4.45	32.00
2000	1.87	2.60	2.62	4.08	2.78	8.48	.11	.00	.06	7.26	8.96	4.44	43.26
Mean	2.06	2.37	3.00	4.18	5.21	3.48	2.15	2.17	3.25	3.85	2.63	2.30	36.65

Stephenville, TX

1992	2.27	4.79	1.74	1.72	4.99	4.87	2.99	2.29	2.98	1.74	3.48	3.54	37.40
1993	2.19	4.04	2.47	3.96	1.57	2.24	.00	1.94	5.20	4.58	1.09	1.36	30.64
1994	1.62	1.21	.48	4.34	6.86	1.65	3.22	3.75	4.64	4.26	4.42	2.87	39.32
1995	.94	.53	3.84	2.20	5.18	3.84	8.55	3.02	3.28	2.58	.62	.69	35.27
1996	.48	.26	1.12	2.60	2.92	2.73	2.78	9.28	4.08	2.87	4.01	.12	36.15
1997	.41	8.30	3.29	4.45	3.45	6.42	1.36	1.74	1.09	4.57	.94	4.17	40.19
1998	2.60	2.53	4.25	.30	4.55	2.33	1.63	.84	3.77	3.61	3.31	2.80	32.51
1999	1.17	.03	1.47	2.01	3.10	1.99	1.38	.05	1.89	2.10	.08	2.53	17.79
2000	1.10	.66	1.87	2.48	2.27	6.91	.08	.00	.26	4.24	5.85	1.49	27.21
2001	3.42	4.99	3.22	.39	2.08	1.38	.00	3.69	3.85	1.06	2.79	1.57	28.45
Mean	1.39	1.87	2.21	2.90	4.95	3.41	2.07	2.50	2.83	3.04	1.82	1.94	30.63

Yoakum, TX

1997	5.50	2.50	8.59	11.55	5.98	7.51	1.12	.95	4.20	14.16	3.59	2.67	68.32
1998	2.31	5.04	1.51	1.92	.29	2.42	0.57	11.40	9.10	15.67	7.09	3.32	60.62
1999	.33	1.01	4.76	.16	4.27	6.99	1.90	1.19	1.00	.51	.33	.77	23.22
2000	6.09	2.44	4.12	2.82	7.13	6.31	2.21	.97	1.17	5.05	9.63	2.87	50.81
2001	3.42	.81	4.60	.67	1.63	2.06	.55	11.54	6.49	3.01	3.26	6.84	44.88
Mean	2.62	2.61	2.07	3.22	4.54	4.18	2.69	2.99	3.94	3.46	2.96	2.52	37.51

Hope, AR

1997	4.18	7.89	5.68	9.91	1.79	5.87	2.40	2.49	1.55	5.32	4.50	5.00	56.66
1998	7.69	6.67	4.35	2.25	3.12	1.35	3.24	3.62	8.92	6.82	3.01	5.47	56.48
1999	8.91	.67	7.29	4.80	4.07	2.23	.11	.75	1.50	3.41	.75	3.44	37.93
2000	1.46	2.52	4.97	2.94	5.03	10.43	.30	.00	3.21	1.15	14.18	3.80	49.99
2001	5.62	8.62	4.19	3.03	4.86	4.14	.33	3.01	2.01	8.35	5.72	8.17	58.07
Mean	3.47	4.11	4.99	4.96	5.36	4.53	4.03	4.18	4.15	3.83	5.33	4.88	53.82

Overton, TX

1997	4.46	8.29	2.94	6.00	1.23	5.70	2.75	3.20	1.50	6.70	3.52	1.80	48.09
1998	7.11	5.18	2.10	2.32	.57	1.88	1.81	2.08	11.80	7.44	5.70	4.24	41.61
1999	6.95	.25	4.11	5.94	5.60	2.39	3.61	.21	2.70	1.84	.24	3.67	37.51
2000	1.81	2.14	3.30	4.71	7.37	2.39	.11	.06	.81	2.59	11.74	5.04	42.07
2001	5.34	5.77	6.73	.44	8.74	8.46	.45	3.30	5.25	3.03	3.12	6.60	57.23
Mean	4.28	3.61	3.76	4.89	5.30	3.46	3.29	2.11	3.75	3.21	3.92	4.14	45.72

Clinton, LA

1997	6.28	9.26	3.39	12.04	4.49	9.46	6.29	3.24	1.15	3.10	4.97	5.85	69.52
1998	11.81	6.63	4.06	7.61	.37	1.82	2.92	3.20	7.07	2.60	2.91	4.41	55.41
1999	6.63	2.51	9.26	.20	5.39	4.83	4.17	2.93	3.56	10.03	1.18	3.89	54.58
2000	2.94	1.28	3.02	1.81	1.79	7.82	5.18	2.29	1.85	.09	9.15	2.46	39.68
2001	6.14	4.82	11.77	.75	1.36	14.86	6.43	5.32	3.83	4.95	1.64	4.04	65.91
Mean	5.32	5.82	5.58	5.30	5.11	4.57	6.09	5.74	4.82	3.24	4.54	5.91	62.04

*Mean is the long-term mean for location.

Table 11-4. Temperature Table

Monthly mean minimum and mean maximum temperature for 1997-2001 at Beeville, College Station, Dallas, Stephenville, Yoakum, Hope, Overton, and Clinton.

					Beeville, TX							
Mean	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min 1997	44	48	57	57	66	72	73	75	70	62	51	42
Min 1998	49	48	53	58	69	77	75	75	74	NA*	58	46
Min 1999	54	58	62	63	68	73	73	73	67	56	53	45
Min 2000	54	54	NA	65	NA	75	72	72	69	62	NA	40
Min 2001	41	50	48	64	67	72	73	74	68	60	57	48
Max 1997	61	66	75	74	83	91	97	98	94	81	70	68
Max 1998	71	70	72	80	91	98	99	95	90	NA	73	66
Max 1999	63	66	69	85	87	91	91	97	92	85	80	70
Max 2000	72	75	NA	82	NA	90	98	97	96	82	NA	61
Max 2001	60	70	68	81	88	95	97	97	88	83	80	68

					College Station, TX							
Min 1997	39	45	52	52	63	70	73	73	69	60	45	39
Min 1998	45	43	47	53	67	75	75	76	74	61	54	42
Min 1999	43	49	51	60	64	73	72	74	66	55	46	38
Min 2000	43	47	54	56	68	72	72	72	67	62	47	36
Min 2001	38	47	44	61	66	72	75	75	68	56	53	43
Max 1997	58	61	73	73	82	88	96	95	92	79	65	60
Max 1998	66	64	68	77	91	98	98	101	96	80	70	61
Max 1999	66	73	72	81	85	90	93	100	93	83	76	66
Max 2000	65	73	75	80	87	90	100	101	95	82	65	55
Max 2001	57	67	65	81	89	91	97	98	88	81	75	64

Dallas, TX

Min 1997	32	37	44	49	59	68	74	71	69	55	41	33
Min 1998	37	38	42	51	66	73	79	76	71	57	48	36
Min 1999	35	41	44	55	60	71	73	75	63	54	48	39
Min 2000	36	42	47	50	63	69	74	76	65	58	39	29
Max 1997	54	55	67	69	88	88	94	91	90	75	59	52
Max 1998	56	57	63	74	89	95	101	98	89	77	63	55
Max 1999	58	65	64	78	82	88	93	99	87	79	73	62
Max 2000	58	68	68	74	85	86	96	100	91	77	57	48

Stephenville, TX

Min 1997	31	38	44	47	58	67	70	68	64	52	38	32
Min 1998	35	35	40	46	62	70	72	70	67	56	45	33
Min 1999	32	39	42	51	59	67	68	70	61	49	44	32
Min 2000	35	40	46	51	64	68	70	71	60	58	38	28
Min 2001	28	36	39	54	61	66	72	70	59	48	45	34
Max 1997	54	57	68	69	79	87	94	94	91	78	61	54
Max 1998	59	58	63	76	91	93	94	91	86	78	67	56
Max 1999	62	68	65	78	83	89	95	102	90	80	74	61
Max 2000	60	68	71	77	88	86	97	101	93	76	57	48
Max 2001	52	57	61	75	84	91	99	95	84	77	68	59

Yoakum, TX

Min 1997	41	45	55	53	63	70	72	72	68	60	47	39
Min 1998	46	45	48	54	66	74	72	66	68	61	53	43
Min 1999	42	48	51	58	64	71	71	70	63	56	51	39
Min 2000	45	51	57	57	67	71	71	71	66	60	48	37
Min 2001	39	46	46	61	65	68	71	71	65	54	51	42
Max 1997	60	63	75	74	84	90	95	97	93	80	67	63
Max 1998	69	67	71	79	91	97	103	105	96	82	73	66
Max 1999	70	74	75	82	89	90	93	100	95	86	80	69
Max 2000	69	73	78	81	87	91	99	98	96	81	68	60
Max 2001	59	68	67	81	88	93	98	98	87	80	74	66

Hope, AR

Min 1997	28	39	42	44	55	65	72	67	63	50	39	32
Min 1998	37	35	40	45	61	70	74	70	68	54	44	36
Min 1999	33	37	39	54	57	67	71	68	58	47	41	32
Min 2000	33	36	43	47	62	66	69	71	61	51	39	25
Min 2001	28	37	39	55	60	65	73	71	60	45	42	35
Max 1997	47	58	69	69	79	85	95	89	89	76	60	51
Max 1998	55	58	62	73	84	92	99	95	90	75	63	56
Max 1999	58	63	63	75	80	87	93	99	87	77	71	59
Max 2000	55	64	67	71	82	85	91	98	89	76	57	45
Max 2001	48	58	59	76	81	86	92	93	81	73	68	57

Overton, TX

Min 1997	34	40	49	48	59	67	NA	NA	NA	51	40	34
Min 1998	39	38	43	50	66	72	75	72	70	58	50	41
Min 1999	41	45	46	58	62	70	73	72	63	53	47	37
Min 2000	37	42	49	54	66	70	72	73	64	58	44	32
Min 2001	35	43	45	59	63	68	74	72	65	52	50	42
Max 1997	53	59	73	70	80	87	NA	NA	NA	78	62	56
Max 1998	60	62	65	74	90	95	101	97	91	78	67	59
Max 1999	62	68	66	78	82	88	92	98	88	80	73	61
Max 2000	60	70	72	74	83	86	95	99	89	78	60	48
Max 2001	52	62	61	78	84	87	92	91	82	76	70	61

Clinton, LA

Min 1997	40	44	53	51	62	69	72	70	66	55	45	38
Min 1998	43	42	47	52	76	72	73	72	78	59	52	45
Min 1999	42	45	46	60	61	69	72	73	63	54	46	39
Min 2000	42	44	51	52	66	69	71	71	63	51	41	33
Min 2001	35	43	44	57	61	66	72	71	65	53	50	43
Max 1997	58	62	74	71	81	85	90	90	90	79	64	59
Max 1998	61	63	69	75	90	93	94	95	86	81	72	63
Max 1999	66	69	70	81	84	88	90	95	87	79	71	62
Max 2000	63	70	75	76	87	91	na	94	91	83	71	57
Max 2001	57	70	67	80	85	86	90	88	85	75	75	66

*not available

Table 11-5. Soil description and corn, sorghum, and Alamo switchgrass yields for College Station, Dallas, and Stephenville, TX; Hope, AR; and Clinton, LA.

Soil type	SCS Land suitability class	Year	Corn grain yields (bushels per acre)	Grain sorghum yield (lb per acre)	Alamo switchgrass biomass yield (tons of dry matter per acre)	
					Date planted	
					1992	1997
College Station, TX						
Weswood silty clay loam	I	1992	79.8	4000	NA	
		1993	98.5	2333	8.41	
		1994	111.5	4700	8.98	
Fine silty, mixed thermic Fluventic Ustochrept		1995	133.5	5286	8.47	
		1996	49.6	3667	4.70	
		1997	105.9	3763	12.41	
		1998	43.1	2654	5.22	10.29*
		1999	117.0	3939	11.24	11.51
		2000			3.29	5.93
		2001			5.15	10.0
Dallas, TX						
Houston black clay	IIe	1992	83	2760	NA	
		1993	61	2229	2.31	
		1994	77	3298	7.50	
Fine, montmorillonitic thermic Udic Pellusterts		1995	50	2945	2.61	
		1996	56	2982	1.16	
		1997	70	2178	6.23	
		1998	54	2130	3.25	9.80*
		1999	116	6136	5.97	9.29
		2000			1.38	8.36

			Stephenville, TX			
Windthorst fine sandy loam	IIe-3	1992	NA	2520	3.57	
		1993	50.8	2091	4.33	
		1994	50	2857	8.21	
Fine, mixed thermic Udic Paleustalfs		1995	77	No report	8.84	
		1996	78.3	2333	7.65	
		1997	78	No report	8.12	
		1998	none grown	1833	8.89	4.45
		1999	none grown	none grown	6.39	5.42
		2000			4.68	5.24
		2001				9.04
			Hope, AR			
Bowie fine sandy loam	IIe-1	1998	145	NA	---	8.12
		1999			---	6.53
		2000			---	98.92
Fine-loamy, siliceous, thermic Fragic Paleudult						
			Clinton, LA			
Dextar silt loam	IIe	1998	90	NA	---	2.44
		1999	62	2200	---	4.11
Fine-silty, mixed thermic Ultic Hapludalf		2000			---	11.28
		2001				

Corn and sorghum grain yields are either county averages taken from the Texas Agricultural Statistics prepared by the USDA and Texas Department of Agriculture Statistical Service or are from local trials.

Alamo switchgrass yields are from plot trials at each location. Data are of a single harvest per season.

*The 1998 Alamo yields from the 1997 planting at College Station and Dallas are from irrigated plots. Section 6

6. 2001 ANNUAL REPORT

SUMMARY OF 2001 ACTIVITIES AND PROGRESS

Summary of Research Progress. The report that follows gives status/results on each of the seven (7) funded tasks. The weather data tables are included as part of the five-year report. The year 2001was wetter than some of the recent years at most of the more easterly sites, but some sites like Beeville and Yoakum had below average rainfall until late August when we received 15 to 20 inches in a few days, bringing our yearly total to above average. Due to budget cuts we terminating data collection at some sites, however we did concentrate on completing data analysis and tasks related to seed and seedling establishment.

Intensive interest exists in the use of soil biological parameters as indicators of soil quality because these parameters respond more rapidly to changes in soil management than does soil organic C (SOC). Soil microbial biomass (SMB) is the most active fraction of soil organic matter and is responsible for nutrient cycling/turnover in soils, is a source/sink of N, and may be used to predict changes in soil quality long before differences are observable as changes in SOC. Results from soil samples collected at four Texas locations and one location each in Louisiana and Arkansas showed that total SOC under switchgrass may be lower compared to other cropping scenarios, especially other adapted forage grasses and forest. Switchgrass had greater SOC than cultivated treatments, however, with SOC under switchgrass expected to become similar to long-term grass and forested systems with time. Although SOC was generally not highest for switchgrass, SMB C/SOC was proportionally greater for switchgrass at most locations, implying potential improvement in soil quality and more active nutrient cycling with switchgrass. The portion of SOC that exists as SMB C has been used as an indicator of soil quality, with increasing proportions indicating enhanced quality. Particulate organic matter (POM) C also represents an active fraction of soil organic matter that has successfully been used to predict longer-term changes in SOC. Soil POM analysis was an added set of analysis for the current year's work, and it appears to be a well correlated to SOC and is much easier to measure in the lab.

"Alamo" switchgrass is still one of our best variety in the long-term studies. In the newer variety trials, most of Taliaferro's "Lowland" types continue to show promise. The "Upland" types are ALL inferior to the "Lowland" types, with the yield difference being in the 2X to 3X range between these two types. At some locations Alamo is still as good as anything, but at other locations, there seems to be an indication that the new lines may be better particularly the Southern Lowland ecotypes. We have enough location years of data to document that there is a critical period for rainfall. Accumulated rainfall for the period from April through July accounts for much of the variation in observed yield at the various locations throughout our region. A single set of soil samples taken in late 2001 show a negative relationship between cultivar yield and nematode concentrations, suggesting that nematodes may be involved in stand performance (and perhaps in stand establishment).

No new field plantings were made this year to attempt to evaluate seedling establishment issues, but a number of controlled environment studies were completed. We now know that rainfall is required at least every 7 days during the seedling establishment period with some variation among soils types. AND in our region, rainfall every 7 days is not a NORMAL occurrence. Temperature and genotype of switchgrass also affects germination rate. Our research suggest that from a temperature standpoint plantings could be made between April and September, and that the Lowdorm selection we have under development germinates faster and is more likely to survive than is Alamo or Blackwell. We are continuing to work on the low dormancy trait, and are working to incorporate low dormancy, low crown-node placement AND large seedling mass all into on set of germplasm. We have identified lines with improved seedling mass at two-weeks after emergence, and have produced seed off of our first polycross nursery and are ready to establish our "second cycle of superior seedling mass" polycross planting. We have also screened the clones that have been selected for low dormancy and identified clones within this population that have superior seedling mass.

We moved our weed control effort into the greenhouse, and evaluated activated carbon sprayed over the row after seeding and before the herbicides were applied. Most all these treatments appear to show promise. This technology that has been used in the grass seed industry in Oregon for over 40 years, but we are unaware of any effort to utilize it on switchgrass. We have also gotten a seed coating company to make us up a small batch of pelleted seed with nutrients and activated carbon. They told me it was difficult to accomplish but they did return some carbon coated seed. We still need to evaluate this to see if there is enough carbon on the seed to provide the needed protection from the herbicides.

The N-rate by fall harvest management study harvested at Hope, and Yoakum in 2001-02 and all mineral and fiber analysis has been completed for all previous years' harvests at Dallas, Hope and Yoakum. Several of the major minerals, including those that are considered to be undesirable for Biofuel quality do show major losses as the harvest is delayed into the fall and winter. In addition, these losses should translate into less mineral removal from the field, allowing for a more sustainable yield of biomass without having to replace minerals removed from the soil. A uniform harvest was taken at the Dallas site in May of 2001, and along with a similar set of harvests that are planned for the Yoakum and Hope sites in May of 2001, we should be able to document if there are any long-term carry-over effects from these different N-treatments as well as harvest dates. Previous years' data as well as this year's data suggests there are minor losses in dry matter as you delay the harvest into the fall and winter. These losses are not large, and along with the improved fuel quality, and reduced mineral removal, some of the later harvest will be dry enough to permit direct cutting and storage (or burning) which may also prove to be a cost saving characteristic. The N response has been fairly flat and quadratic, with the fitted data indicating that yields maximize at about 165 kg of N per hectare, but since these responses are quadratic, economic maximums are likely closer to 120 kg/ha. In addition, lodging is quite severe at some sites when the N rates are pushed beyond the 120 kg/ha range.

Preliminary yields of some alternative species appear real promising including *Arundo donax* with yields in the 9000 lb/A range with below average summer rainfall. The *Desmanthus bicornutus* yields were also encouraging with yields in the 5000 to 7000 lb/A range for this dryer than average year. In addition, this legume did not respond to added P-fertility, and the lowest seeding rate (3 lb/A) provided significantly more dry matter yield than the 10 or 20-lb seeding rate. The encouraging thing is that this summer growing perennial legume is of similar stature as switchgrass, so it could potentially be planted with switchgrass to provide a sustainable production system with limited N inputs. This legume is also an excellent plant for wildlife, so there could be an excellent secondary benefit from growing it with switchgrass.

We obtained some additional yield estimates for sorghum and corn stubble and grain from 2 location in Texas. The sorghum stubble yields may be high enough to justify harvesting them, but the corn stubble yields are likely too low to justify the cost of harvesting it. We are having trouble getting good consistent data on Corn and sorghum yields close to the sites where we have switchgrass, so we can not update the tables as requested. Texas Agricultural Statistics' last report is for 1998, and it only reported corn yields by District.

A short plan of work is attached. Since we have been promised a no-cost extension in time and we have students that still have more than a year to go to complete their theses/dissertations, we felt like we needed to indicate what we had planned for 2002. We also have some non-student related work that we need to complete, analyze and publish in the coming months. If you will review our publications list, there are several publications listed as "Planned" for 2002 or 2003. If you review this carefully, you will see that we have proposed authors, titles, and journal outlets listed for each. This means we have identified who will take the lead in getting these papers published. We have every intention of completing this project and publishing the results. Most tasks only require additional data analysis and interpretation, but there are a couple tasks that will require additional field/greenhouse/or laboratory evaluation.

Publications. Section 4 of this report lists the publications associated with this project. The total publications for the 10 years is 155, which includes 46 refereed Journal papers, 4 Book Chapters, 23 Proceedings papers, 7 Grant reports, 4 Masters Theses, 3 Ph.D. Dissertations, 44 Abstracts, 19 Presentations, and 5 Field Day reports. Of these 155 total, 44 publications have a 2001 or later date, including 22 of the 46 refereed Journal papers.

Professional Activities. Bill Ocumpaugh attended the Subcontractors meeting in Memphis TN. Bill Ocumpaugh, Gerald Evers and Kim Cassida attended the AFGC meetings in Springdale, AR. Frank Hons, Bill Ocumpaugh, James Read, Jim Muir, Kim Cassida, and Mark Hussey attended the ASA/CSSA/SSSA meetings in Charlotte, NC.

PUBLICATIONS (2001 AND LATER) TEXAS/ARKANSAS/LOUISIANA PROJECT

Refereed Journals

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ACCOMPLISHMENTS BY TASK FOR 2001

TASK 1: BIOLOGICAL, ECONOMIC AND PHYSICAL CONSTRAINTS TO SWITCHGRASS BIOMASS PRODUCTION (Terminated).

TASK 2: CHANGES IN SOIL NITROGEN AND SOIL QUALITY ASSOCIATED WITH SWITCHGRASS PRODUCTION

Objectives:

1. **Determine the effects of switchgrass production on soil C sequestration, soil microbial biomass C and N , soil C and N dynamics, and particulate organic matter C compared to other forage grasses and cropping/vegetation systems.**

2. **Utilize the above measurements plus other selected soil properties to estimate effects of switchgrass production on soil quality as compared to other forage grasses and vegetation systems.**

Background. Switchgrass has been evaluated over the past 15 years as a possible energy crop, with generally favorable results. Switchgrass also appears to partition considerable C below ground, which could be important for soil C storage, especially with the added emphasis on soil C sequestration as a means of mitigating increasing atmospheric CO_2. Greater knowledge of the short- and long-term effects of switchgrass production on soil biological and chemical properties is needed to assess effects on sustainable land management and the environment. Soil biological parameters are currently being used as indicators of soil quality because these parameters respond more rapidly to changes in soil management than does total soil organic C (SOC). Soil microbial biomass (SMB) and associated activity characteristics have been successfully used as predictors of soil C and N dynamics. SMB is the most active fraction of soil organic matter and may frequently be used to predict changes in soil quality long before the difference can be observed as a change in soil organic matter content. Particulate organic matter (POM) C also represents an active fraction of soil organic matter that has successfully been used to predict longer-term changes in SOC.

2001 Research Results and Discussion. Soil samples under switchgrass, other forage grasses, cultivated cropping systems, and forest were collected at Yoakum, College Station, Stephenville, and Dallas in Texas and at Clinton, Louisiana and Hope, Arkansas. The same forages, cropping systems, and treatments were not available at all sites (Table 2-1). Soil samples were taken at all sites in March, 2001. Sampling depths at all locations were 0 to 5, 5 to 15, and 15 to 30 cm. Samples were placed in heavy-duty plastic zip-lock bags and refrigerated until analysis. Soil characteristics included soil organic C and total N (Mebius and Kjeldahl methods), initial inorganic N (extraction with 2 *M* KCl), microbial biomass C and N (chloroform fumigation/incubation without subtraction of controls), soil C and N mineralization (24-day laboratory incubations), basal soil respiration (laboratory incubation), and POM-C and -N (sodium phosphate dispersion, passing through a 0.053-mm screen, Mebius and Kjeldahl methods for C and N of materials remaining on the screen following washing with deionized water). Analyses of samples are complete, except for those from Yoakum and Hope.

Greater than average precipitation was received during the pre-season and early growing season at many study locations. Rainfall essentially stopped in early June/July at most locations, creating very hot and dry conditions for the remainder of the summer.

Table 2-1. Cropping systems sampled at different locations for Task 2, 2001.

Location	Cropping designation	Description	Soil Series
Yoakum, TX	Switchgrass	Alamo switchgrass planted 9/97. Treatments include time of fall harvest and N rate.	Strabor fine sandy loam
	Coastal	Long-term Coastal bermudagrass plots with N rate variable.	
	Oat/Peanut	Oats/peanut rotation near the above treatments.	
College Station, TX	Sor-whe-soy	19-year old tillage, rotation, N rate study. Rotation sampled was sorghum-wheat-soybean, conventional tillage, optimal N, sorghum planted at sampling.	Weswood silt loam
	Kleingrass 1992	Kleingrass plots established in 1992 receiving 1 or 2 cuttings/year.	
	Alamo 1992	Alamo switchgrass plots were established in 1992 receiving 1 or 2 cuttings/year.	
	Alamo 1997	Alamo switchgrass plots established 7/97.	
Stephenville, TX	Alamo 1992	Alamo switchgrass established in 1992; part of N-P row-spacing study.	Windthorst fine sandy loam
	Coastal	Coastal bermudagrass plots receiving varying rates of dairy manure for past 7 years.	
	Alamo 1997	Alamo switchgrass planted in 20-acre field in 4/97.	
	Whe-Peanut	Nearby cultivated area with wheat/peanut rotation.	

Location	Cropping designation	Description	Soil Series
Dallas, TX	Alamo 1992	Alamo switchgrass established in 1992; part of N rate, fall harvest study.	Houston Black clay
	Coastal	Adjacent long-term (> 25 years) Coastal bermudagrass pasture with cattle grazing.	
	Whe-Cot	Adjacent cultivated field with cotton/wheat rotation. Land bedded for cotton planting when sampled.	
	Alamo 1997	Alamo switchgrass established in 1997.	
Clinton, LA	Alamo	Alamo switchgrass plots established in 8/97.	Providence Sandy loam
	Caddo	Caddo switchgrass plots established in 8/97.	
	Bahia	Adjacent long-term bahiagrass pasture.	
	Forest	Adjacent long-term forested area.	
Hope, AR	Alamo	Alamo switchgrass plots established in 1997.	Sandy loam/clay loam
	Caddo	Caddo switchgrass plots established in 1997.	
	Grass	Bahiagrass/fescue pasture near plots.	
	Forest	Long-term forested area near plots	

Soil organic C (SOC) varied with location, cropping treatment, and soil depth. Samples from Dallas had SOC concentrations that generally were at least twice that of other locations, probably because of the high montmorillonitic clay content of the Houston Black clay soil which helps protect SOC from decomposition (Fig. 2-1) (figure legends for each location are described in Table 2-1). Samples from long-term (> 25 yrs) coastal bermudagrass pasture exhibited the highest SOC values at 0 to 5 cm, followed by Alamo switchgrass planted in 1992, Alamo switchgrass planted in 1997, and the cultivated wheat-cotton rotation, with each mean being significantly different from the others. Tillage was very detrimental to SOC maintenance/accumulation in this soil, with SOC means being statistically the lowest at all depths. A comparison of differences in SOC to a 30-cm depth between the cultivated wheat-cotton system and the other vegetation treatments showed an additional 30,000, 22,000, and 41,000 kg C ha^{-1} for Alamo switchgrass planted in 1992, switchgrass planted in 1997, and long-term coastal bermudagrass (Fig. 2-2). This calculation assumes that soils from all treatments had similar SOC concentrations at the beginning of the study. The difference between the above values for switchgrass planted in 1992 and 1997 divided by the difference in stand age (five years) resulted in a SOC accumulation rate of 1,600 kg C ha-30 cm^{-1} yr^{-1} for Alamo switchgrass at this location. This calculation also assumes that the rate of accumulation was linear over this time period.

SOC from the 0-to-5 cm depth at Stephenville was greatest under coastal bermudagrass followed by Alamo switchgrass planted in 1992, switchgrass planted in 1997, and the cultivated wheat/peanut rotation. All vegetation treatments were significantly different from each other (Fig. 2-3). A similar calculation as for Dallas soils showed that an additional 11,000, 5,000, and 25,000 kg C ha^{-1} to a 30-cm depth accumulated under Alamo switchgrass planted in 1992, switchgrass planted in 1997, and long-term coastal bermudagrass compared to the cultivated wheat/peanut treatment (Fig. 2-4). Smaller increases in SOC with the grasses compared to Dallas may be due to faster SOC oxidation in Windthorst sandy loam compared to Houston Black clay. A similar calculation as for Dallas soils indicated a switchgrass C accumulation rate of 1,200 kg C ha-30 cm^{-1} yr^{-1}.

Samples from the 0-to-5 cm depth at the College Station location exhibited the greatest SOC concentration with either Alamo switchgrass or Kleingrass planted in 1992 (Fig. 2-5). Samples from plots of Alamo switchgrass planted in 1997 and the cultivated sorghum-wheat-soybean rotation showed significantly lower concentrations. When SOC to a 30-cm depth for the grass treatments was compared with the cultivated treatment, changes in SOC of 1300, -1100, and 800 kg C ha^{-1} were observed for Alamo switchgrass planted in 1992, switchgrass planted in 1997, and Kleingrass planted in 1992 (Fig. 2-6). Why lower differences in SOC accretion for grasses occurred at College Station compared to the other sampling locations is not known, although organic C return through crop residues in this cultivated cropping system was likely significantly greater than at other locations because of the more intensive nature of this rotation (three crops every two years, and grain sorghum and wheat which produce significant residues).

At Clinton, LA, SOC was highest for long-term bahiagrass pasture and forest and lower for Caddo and Alamo switchgrass planted in 1997 (Fig. 2-7). Switchgrass had been growing for less than four years at the time of sampling, which probably contributed to this result.

Overall, SOC was highest in samples from Dallas, intermediate for samples from Clinton, and Stephenville, and least in College Station samples. SOC generally decreased with increasing sand content of the soils and also decreased with depth at all locations. Samples from cultivated treatments exhibited the least decrease in SOC with depth, probably due to incorporation of plant residue with tillage, but in general had the lowest SOC concentrations.

Soil total N tended to follow similar trends as SOC at most locations (data not shown). The C:N ratio of soil organic matter generally varied little with depth and averaged 15.1, 11.3, 19.5, and 15.4 at Dallas, Stephenville, College Station, and Clinton, respectively. Soil C:N ratios were significantly lower in coastal bermudagrass and cultivated plots compared to soil from switchgrass plots at Dallas and Stephenville, indicating more rapid decomposition with bermudagrass or tillage than with switchgrass. Manure from cattle grazing the coastal bermudagrass pasture at Dallas and dairy manure addition to bermudagrass at Stephenville may also have contributed to lower C:N ratios.

Soil microbial biomass C (SMBC) is the most active fraction of SOC. Soil microbial biomass is responsible for nutrient cycling/turnover in soils and can serve as both a source (mineralization) and sink (immobilization) for N. Trends in SMBC were generally similar to those for SOC (Figs. 2-8 to 2-11). Greater microbial biomass normally indicates a greater active soil organic matter pool. SMBC followed the order of Dallas > College Station, Clinton > Stephenville. As expected, soil microbial biomass N followed SMBC (data not shown). Coefficients of determination (r^2) between SMBC and SMBN in the order of the above sites were 0.861, 0.922, 0.962, and 0.640 (P for all regressions < 0.001).

The fraction of SOC that exists as SMBC has been reported to be a sensitive indicator of changes in soil quality. Increasing values of SMBC/SOC may signal enhancement of soil quality. The fraction of SOC as SMBC at Dallas in the 0- to 5-cm depth was greatest for Alamo switchgrass planted in 1992 (Fig. 2-12). At deeper depths, SMBC/SOC was greatest for coastal bermudagrass followed by switchgrass planted in 1992. Lowest values were always noted for the cultivated treatment. The cultivated wheat-peanut treatment usually resulted in the greatest fraction at Stephenville, while coastal bermudagrass resulted in the lowest proportions (Fig. 2-13). Reasons for these trends are not known. Only small differences in this parameter between vegetation treatments were noted at College Station, but Alamo switchgrass planted in 1992 gave the highest results (Fig. 2-14). The fraction of SOC as SMBC in samples from Clinton were greatest for bahiagrass pasture and similar, but lower, for switchgrass and forest (Fig. 2-15). The percentage of SOC as SMBC across all locations ranged from approximately 3 to 7%.

Soil C mineralized in 24 days was very highly related with SMBC at all locations, with r^2 values ($P < 0.001$) ranging from 0.830 to 0.947. The relationship for Dallas is shown in Fig. 2-16. The average fraction of SMBC assumed mineralized in 24 days was 0.398, 0.457, 0.539, and 0.581 for Dallas, Stephenville, College Station, and Clinton samples. Treatments that showed the highest SMBC also exhibited the greatest soil C mineralization. Both SMBC and C mineralization decreased with depth. Cumulative soil C mineralized over time is given in Figs. 2-17 to 2-20 for Dallas, Stephenville, College Station, and Clinton. Cumulative soil C mineralized was especially greater for soils under coastal bermudagrass. Trends for net soil N mineralized were similar to those for cumulative soil C mineralized.

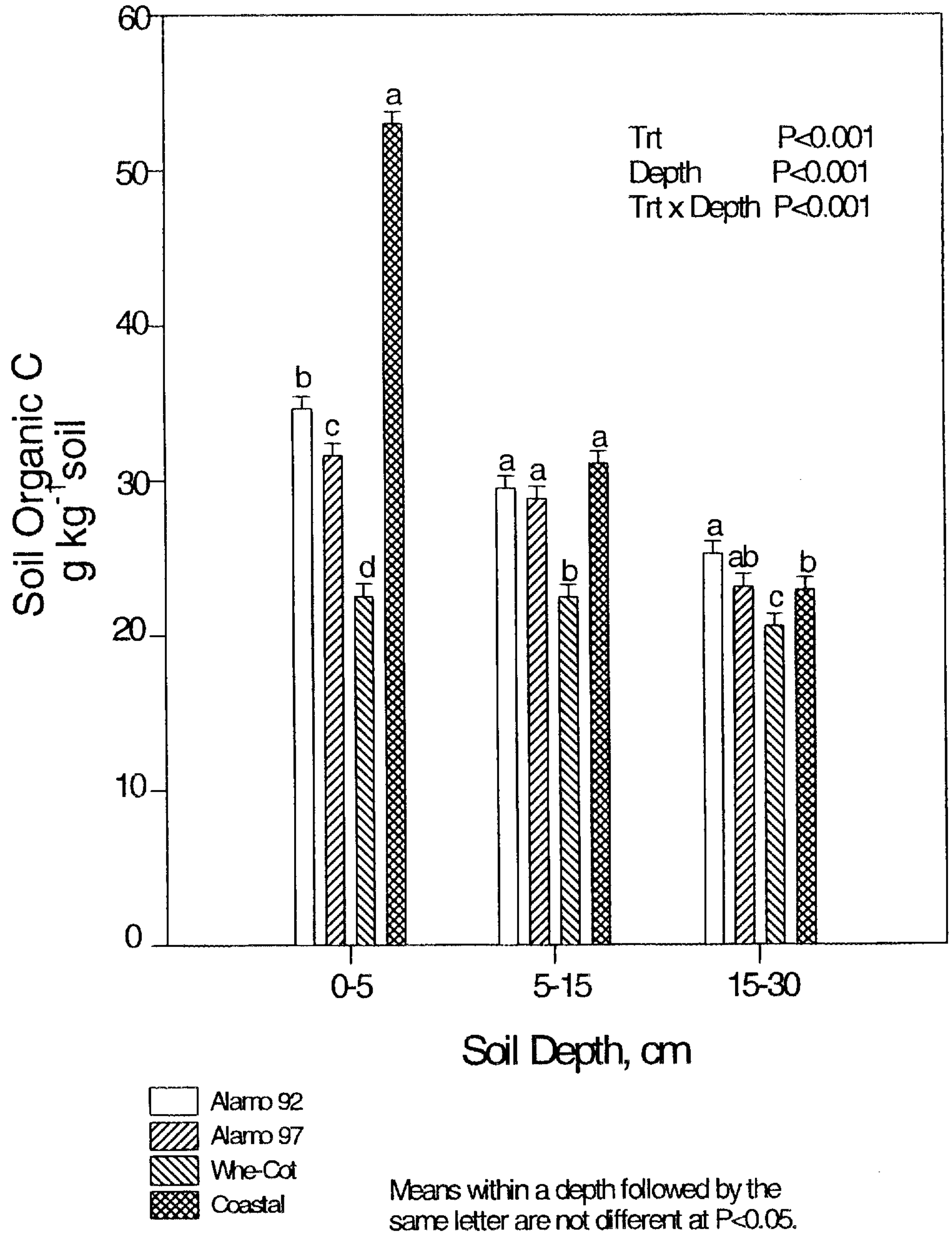
The fraction of SOC mineralized in 24 days might also be used to estimate relative microbial availability or residence time of the SOC pool. Treatments exhibiting a greater fraction would contain organic matter that was more readily oxidizable and would theoretically turn over, or be lost, more quickly from soils. Cultivated treatments generally exhibited lower fractions than switchgrass treatments, likely because decomposition was more complete prior to soil sampling compared to the switchgrass treatments (Figs 2-21 to 2-24). This fraction decreased with depth at all locations, indicating that the quality of SOC is poorer with depth or conditions for decomposition, such as aeration, are not as optimal. Net soil N mineralization followed similar patterns to soil C mineralization (data not shown). Coefficients of determination (r^2) for soil C mineralized vs. net soil N mineralized in 24 days were 0.602, 0.686, 0.849, and 0.517 for Dallas, Stephenville, College Station, and Clinton samples. All regressions were significant at $P < 0.001$. Treatments resulting in the greatest concentrations of SOC also exhibited the greatest soil N mineralization.

Particulate soil organic (POM) C has been reported to be a reliable predictor of long-term changes in SOC and theoretically represents a relatively active fraction of SOC. The concentration of POM-C per unit of soil was not an adequate predictor of activity, such as the fraction of SOC mineralized in 24 days. The fraction of SOC as POM-C , however, mirrored this activity characteristic (Figs. 2-25 to 2-28). Relationships between attributes of POM C and N and soil biological activity characteristics were as good or better than those for SMB C and N and activity characteristics. POM is more rapidly determined than

SMB by fumigation/incubation and might be more widely used as an indicator of potential long-term changes in SOC and soil quality.

Special thanks are extended to Bill Ocumpaugh, James Muir, James Read, Brad Venuto, and Kim Cassida and their staffs for supplying soil samples and to Fugen Dou for analyses.

Figure 1
Vegetation and soil depth effects on soil organic carbon - Dallas,TX, March 2001.



Means within a depth followed by the same letter are not different at P<0.05.

Figure 2
Additional soil organic C storage as compared to the wheat-cotton treatment, 0-30 cm depth, Dallas, TX, March 2001.

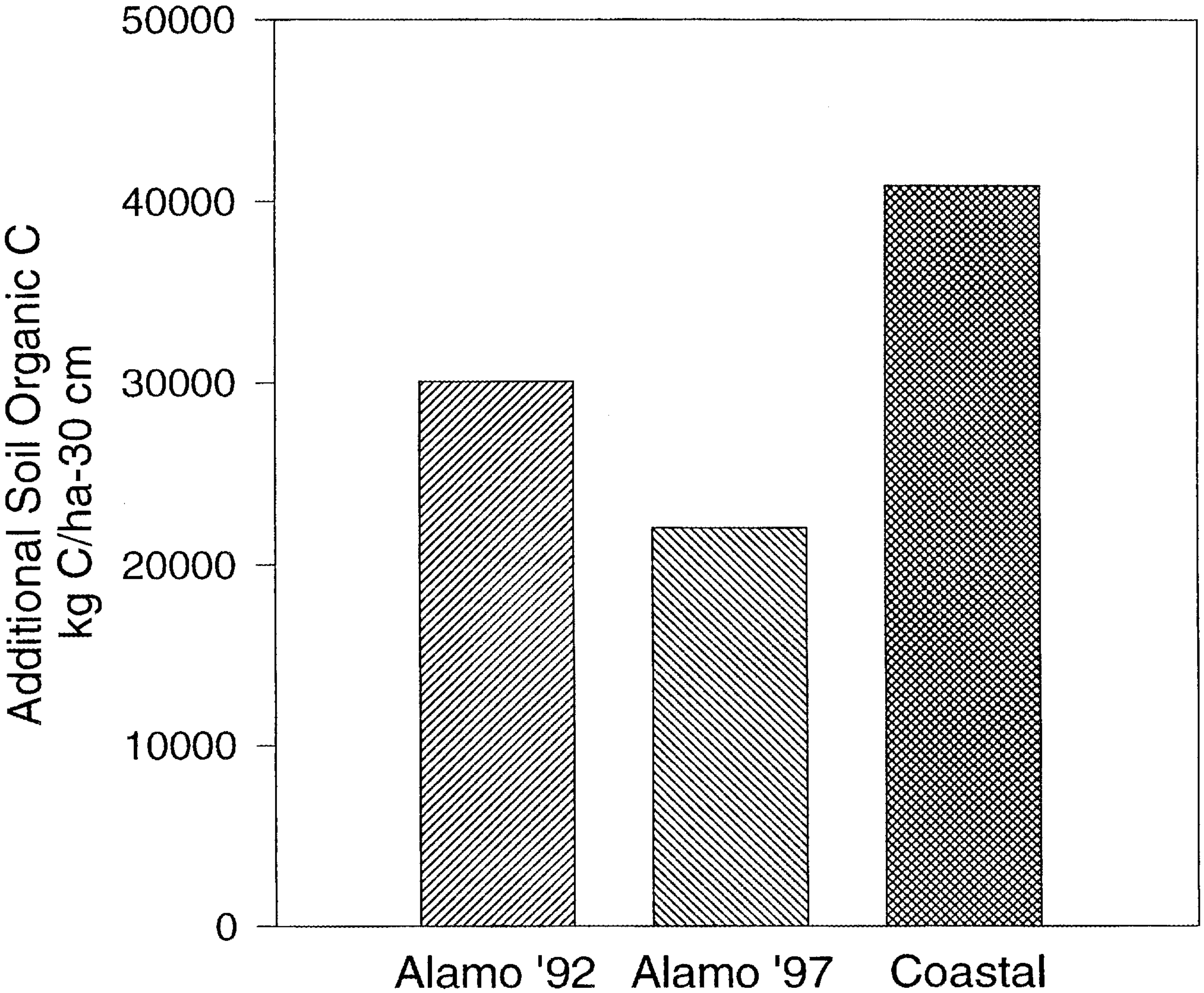
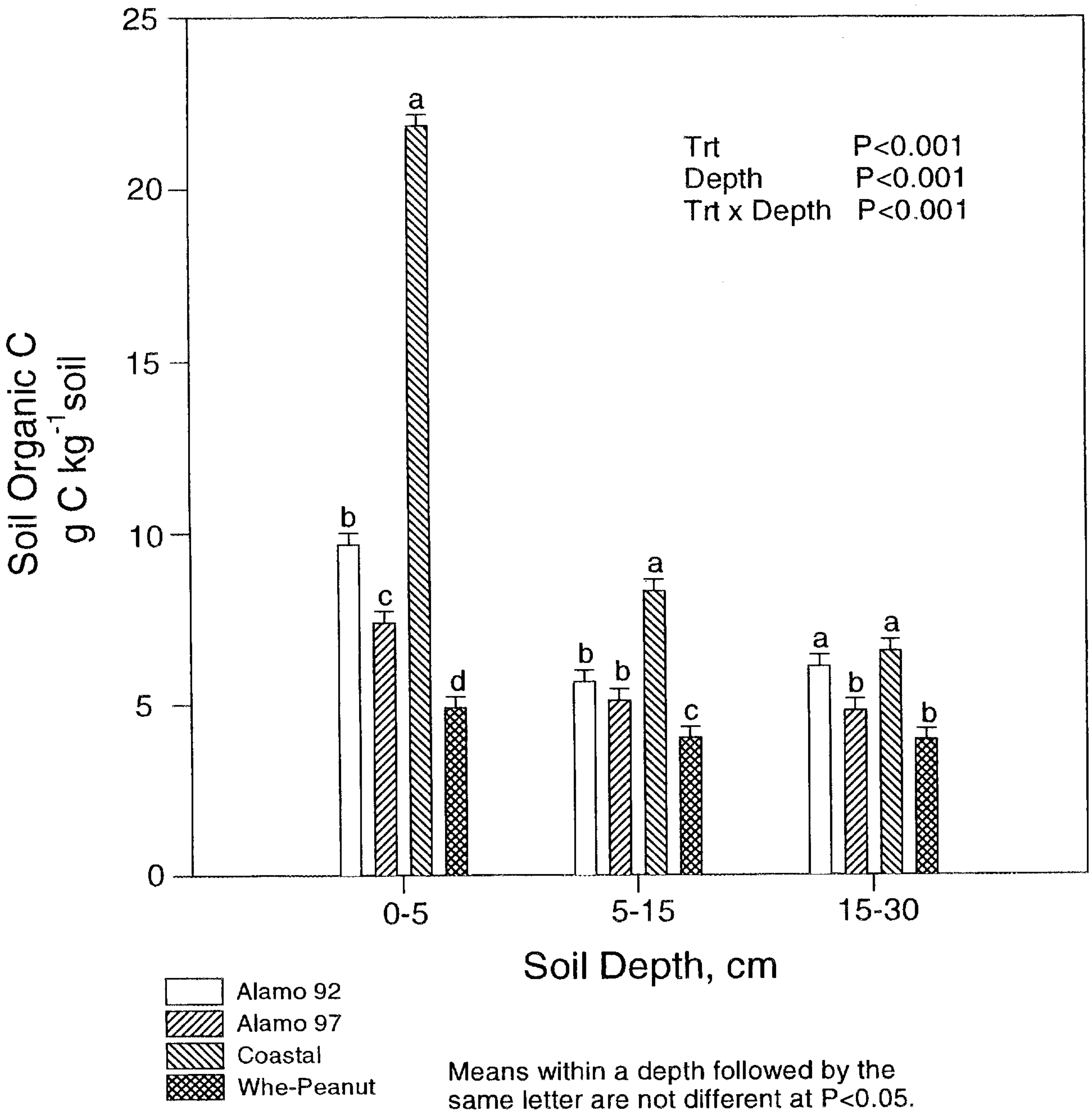


Figure 3
Vegetation and depth effects on soil organic carbon - Stephenville, TX, March 2001.



Means within a depth followed by the same letter are not different at P<0.05.

Figure 4
Additional soil organic C storage as compared to the wheat-peanut treatment, 0-30 cm depth, Stephenville, TX, March 2001.

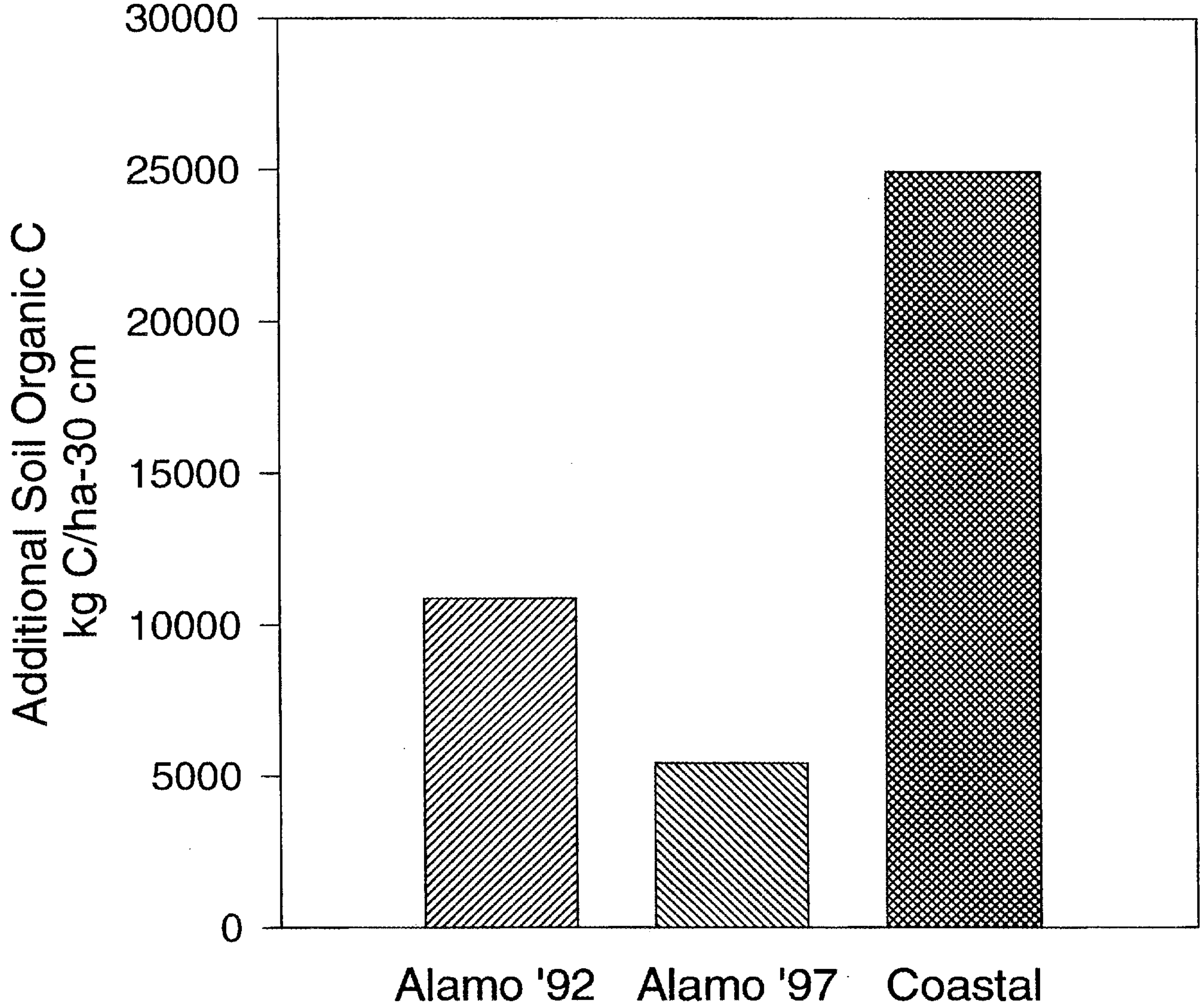
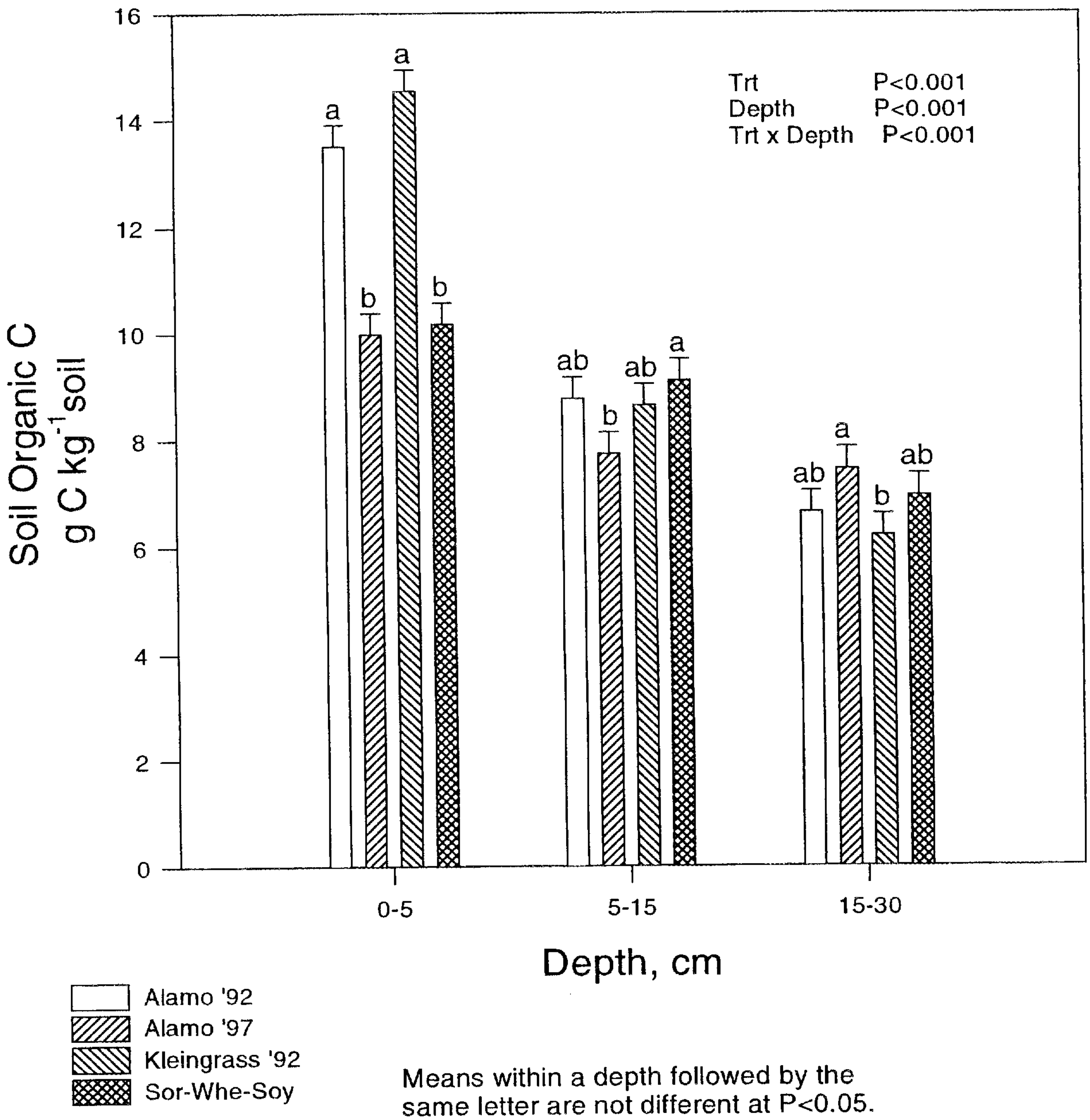


Figure 5
Vegetation and depth effects on soil organic carbon - College Station, TX, March 2001.



Means within a depth followed by the same letter are not different at $P<0.05$.

Figure 6
Change in soil organic C storage as compared to the sorghum-wheat-soybean treatment, 0-30 cm depth, College Station, TX, March 2001.

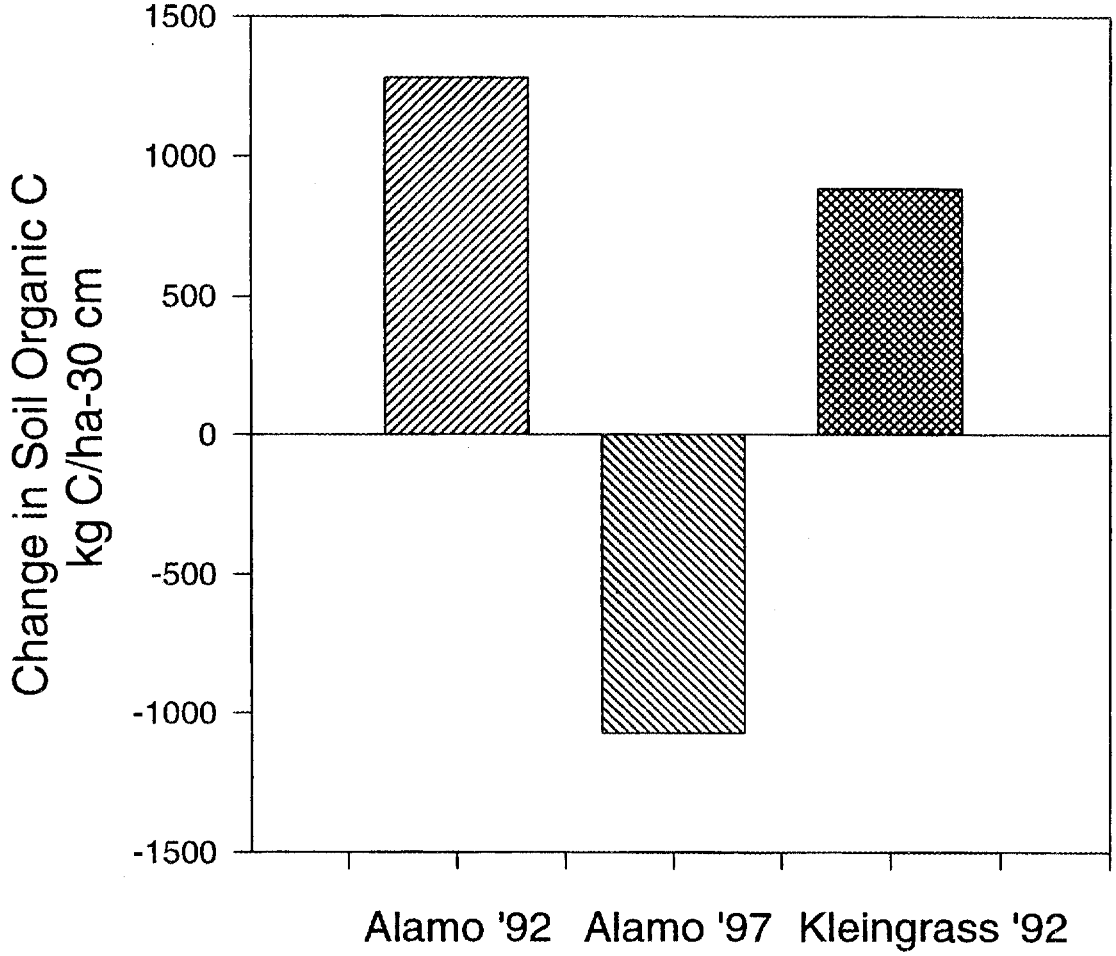
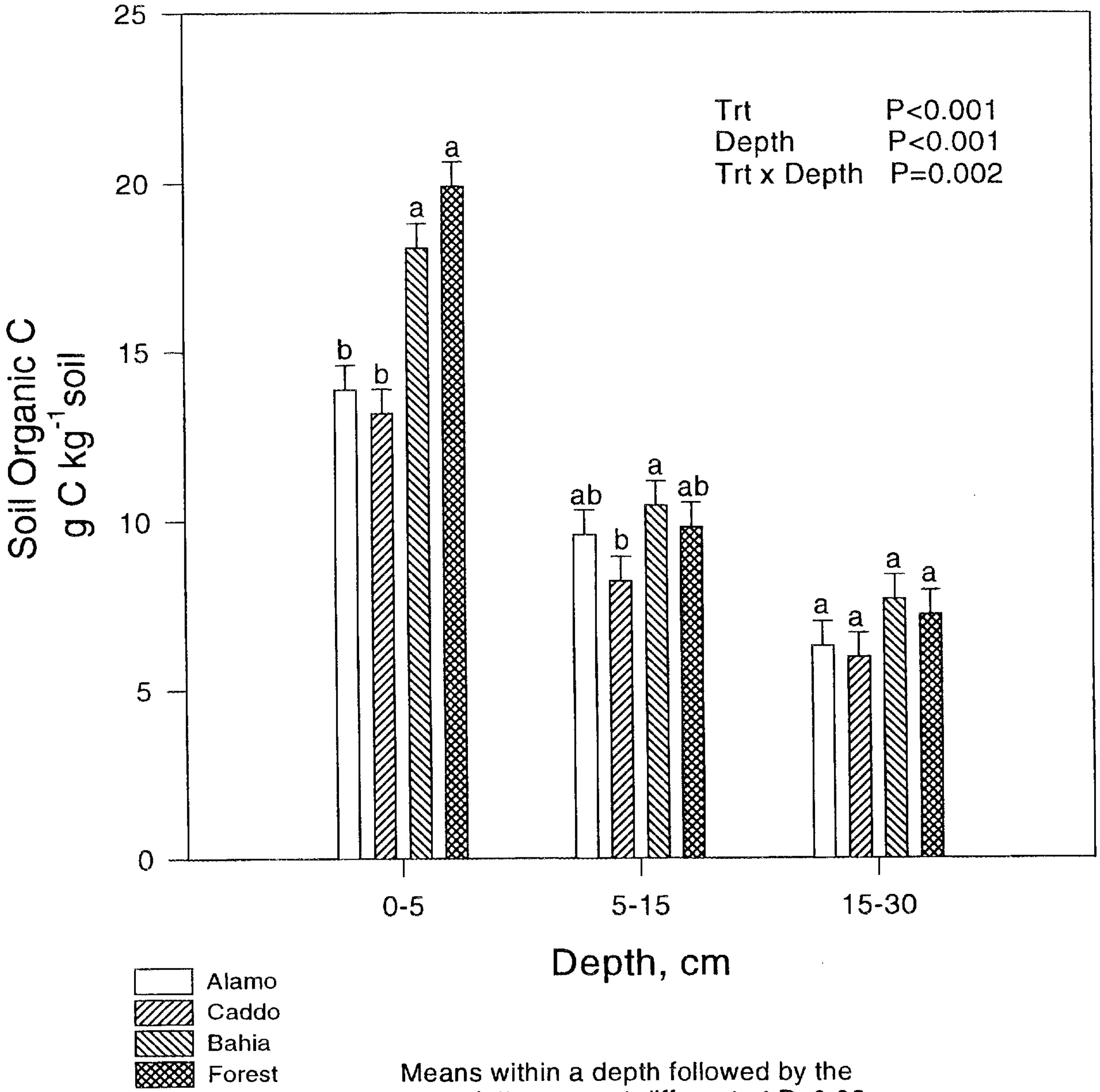


Figure 7
Vegetation and depth effects on soil organic carbon - Clinton, LA, March 2001.



Means within a depth followed by the same letter are not different at $P<0.05$.

Figure 8
Vegetation and depth effects on soil microbial biomass carbon - Dallas,TX, March 2001.

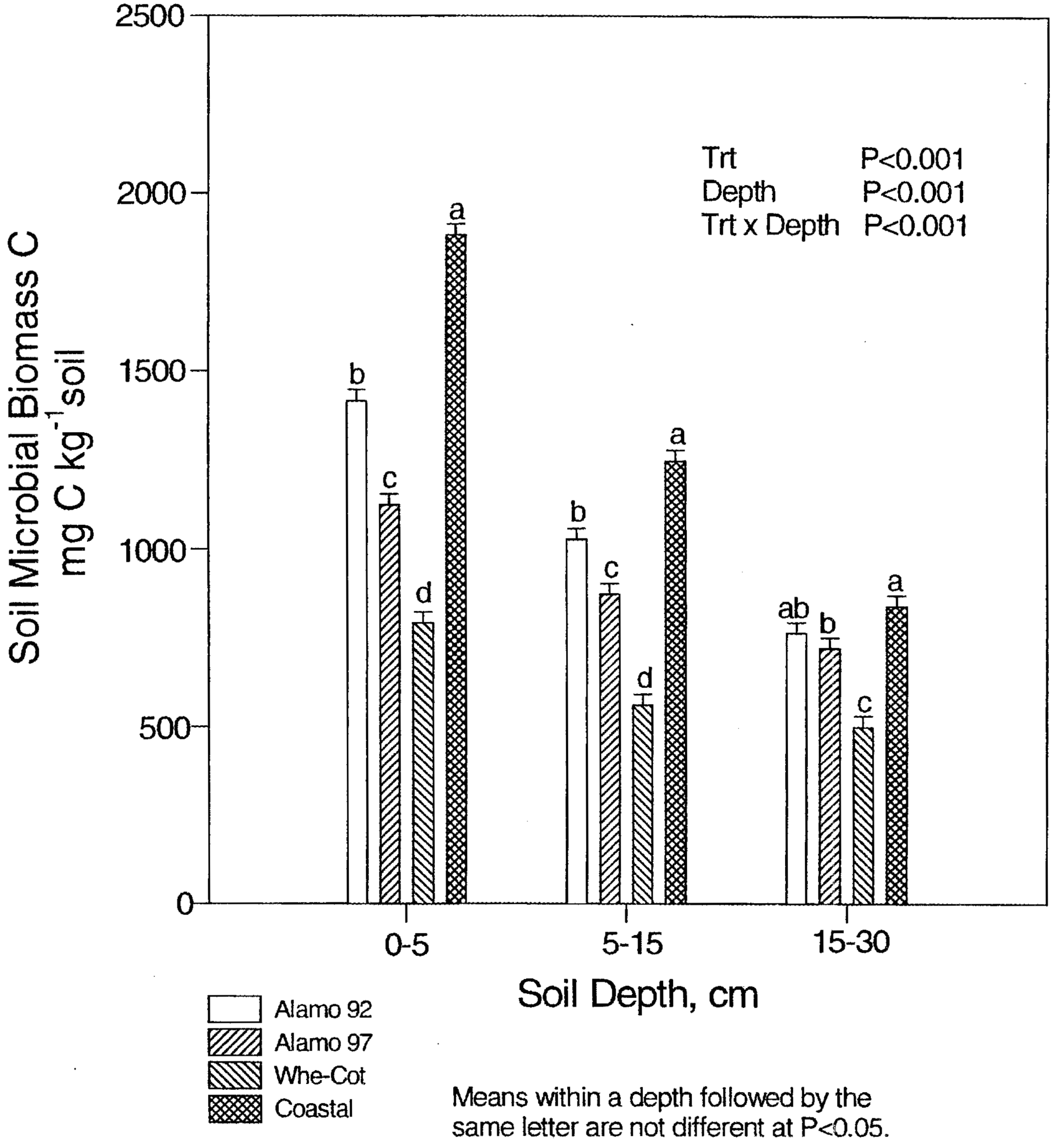
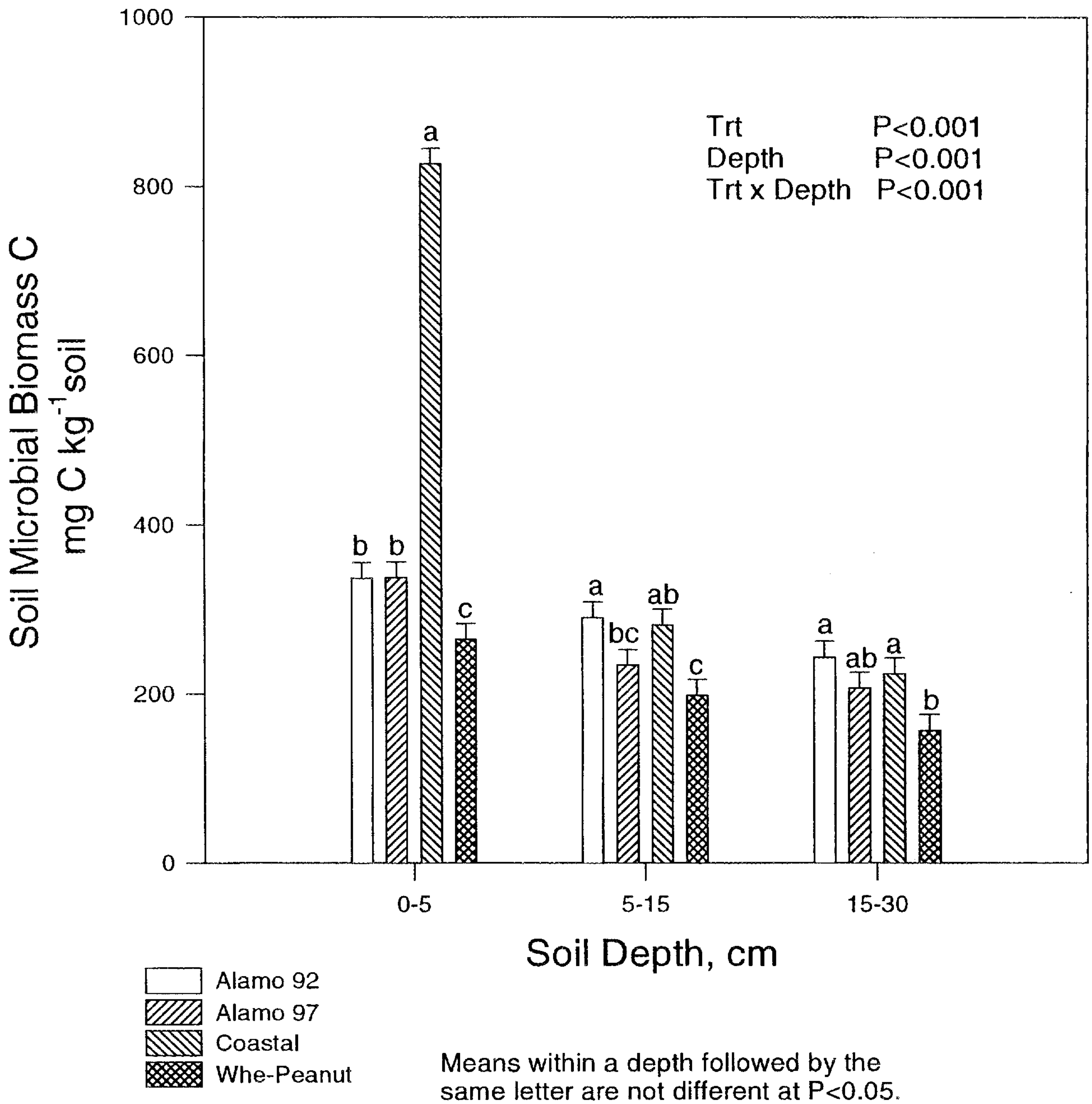


Figure 9
Vegetation and depth effects on soil microbial biomass carbon - Stephenville, TX, March 2001.



Means within a depth followed by the same letter are not different at P<0.05.

Figure 10
Vegetation and depth effects on soil microbial biomass carbon - College Station, TX, March 2001.

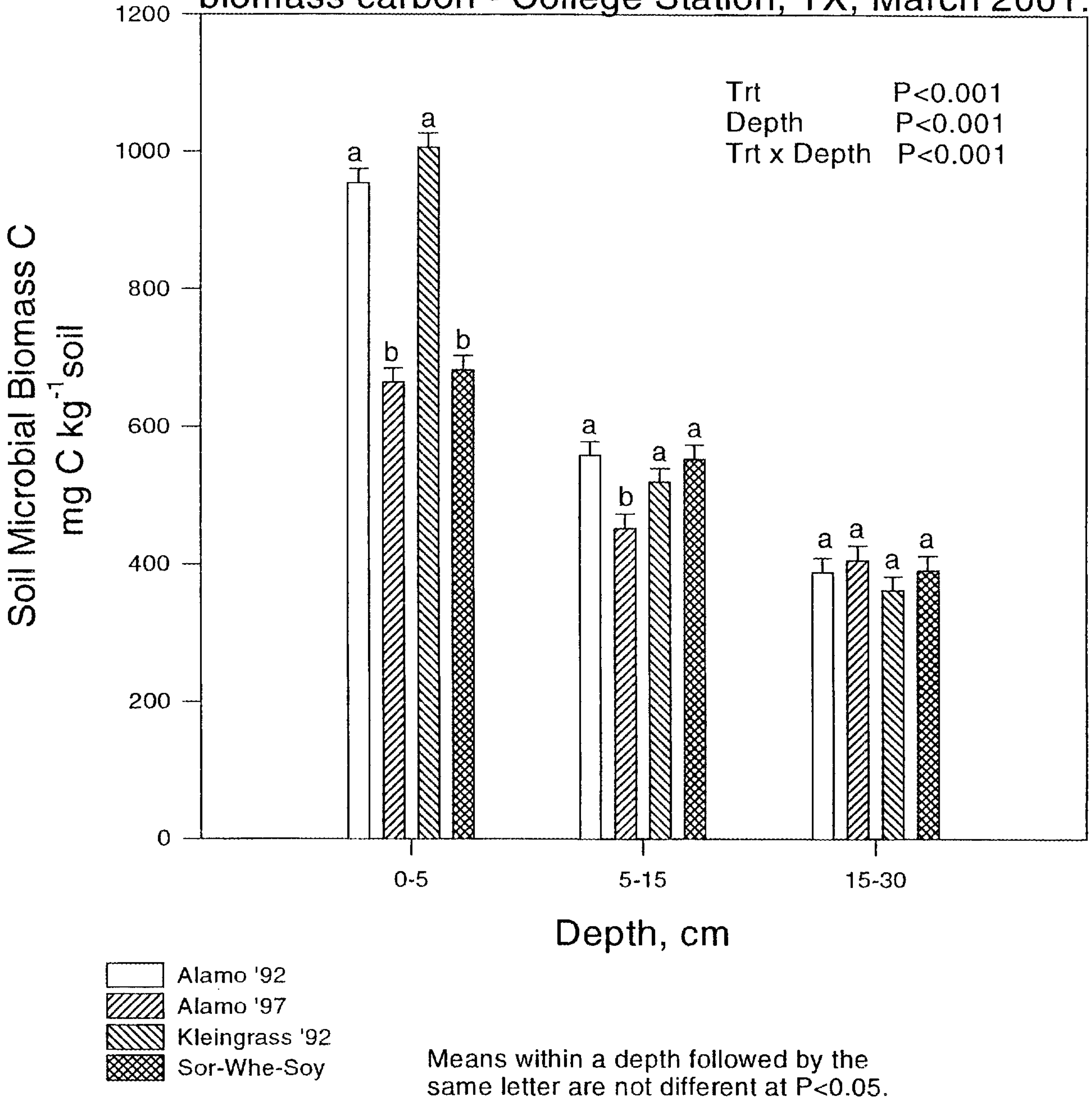
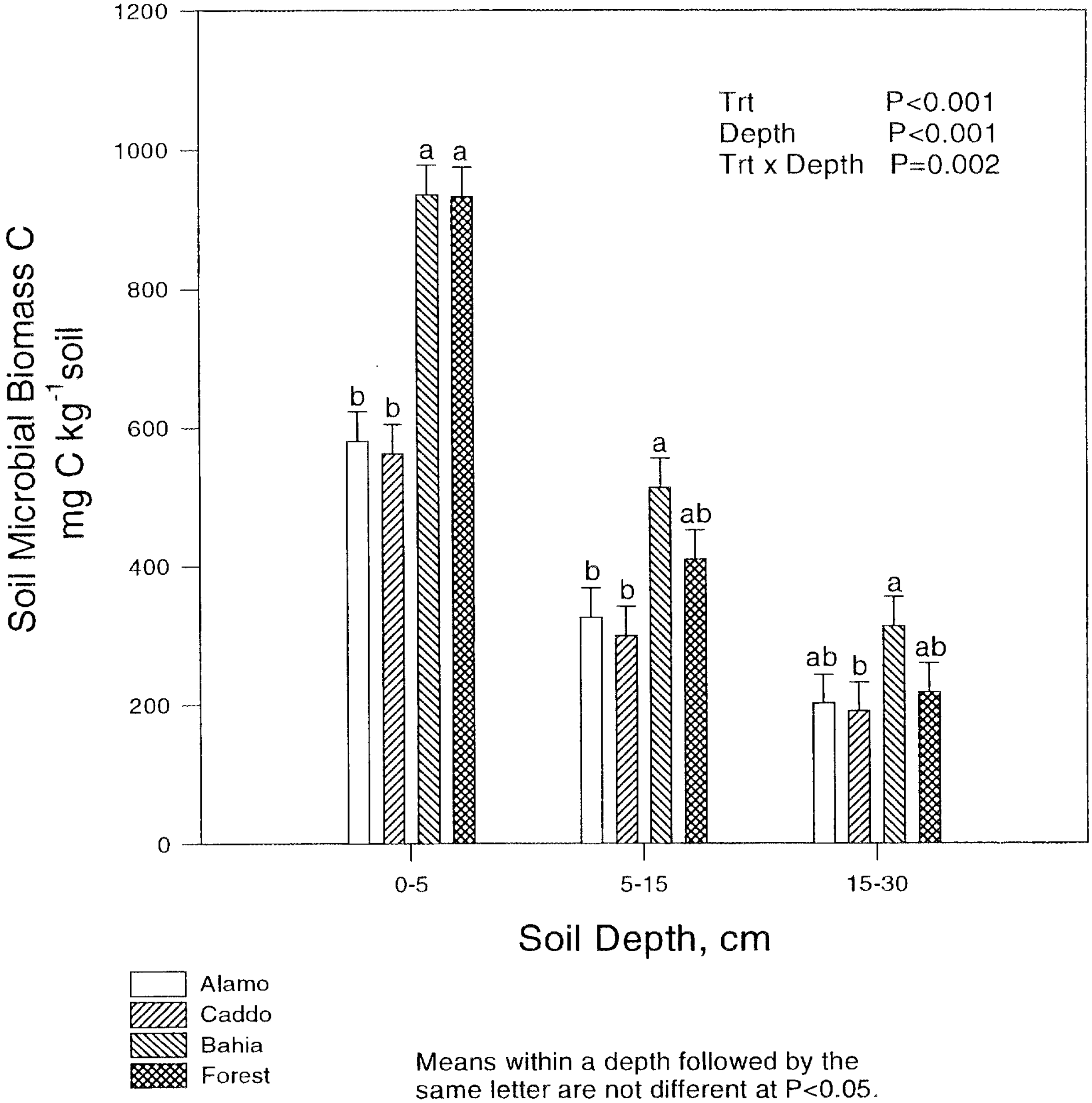


Figure 11
Vegetation and depth effects on soil microbial biomass carbon - Clinton, LA, March 2001.



Means within a depth followed by the same letter are not different at $P<0.05$.

Figure 12
Vegetation and soil depth effects on the fraction of soil organic C as microbial biomass C - Dallas, Tx, March 2001.

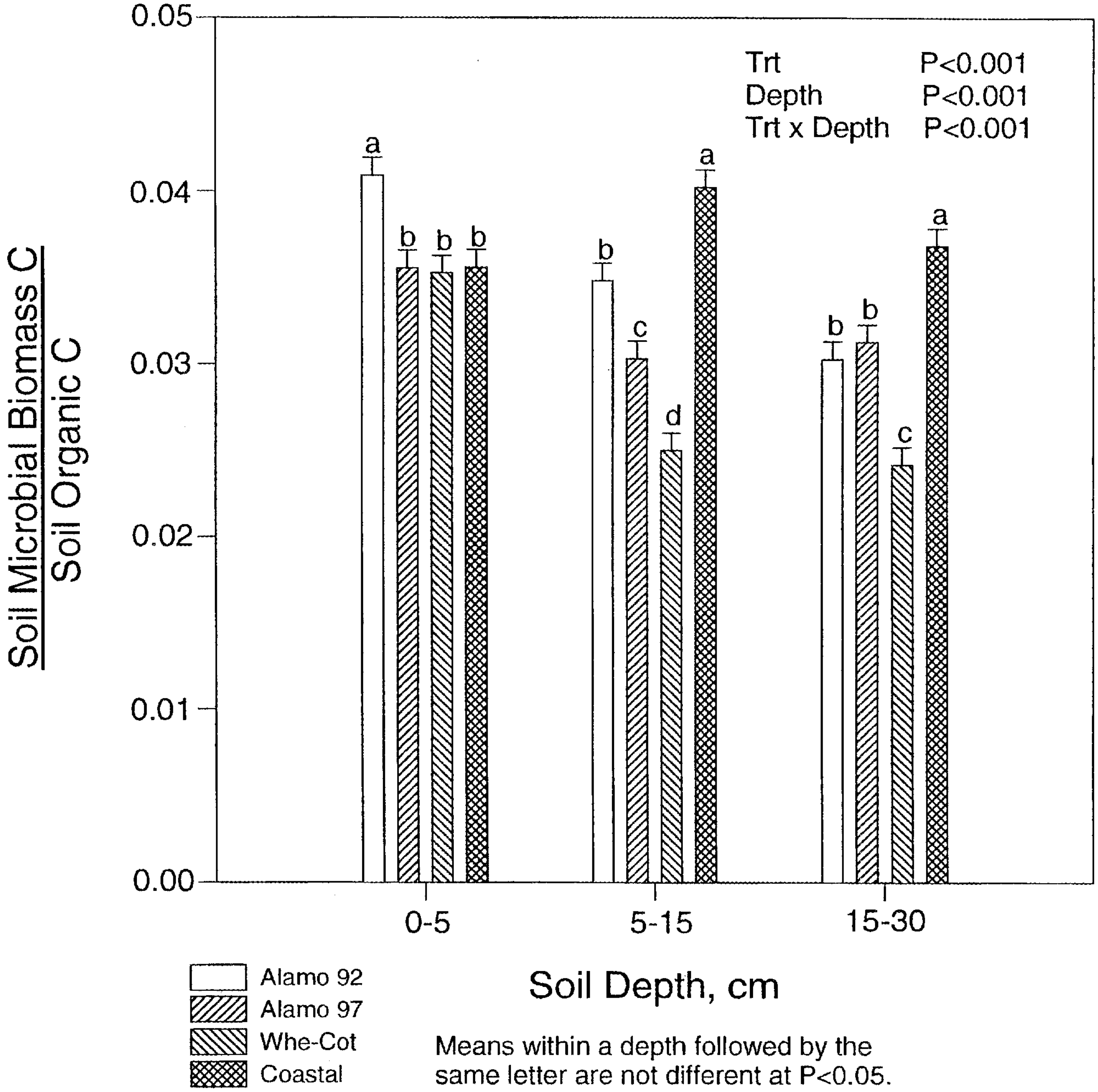
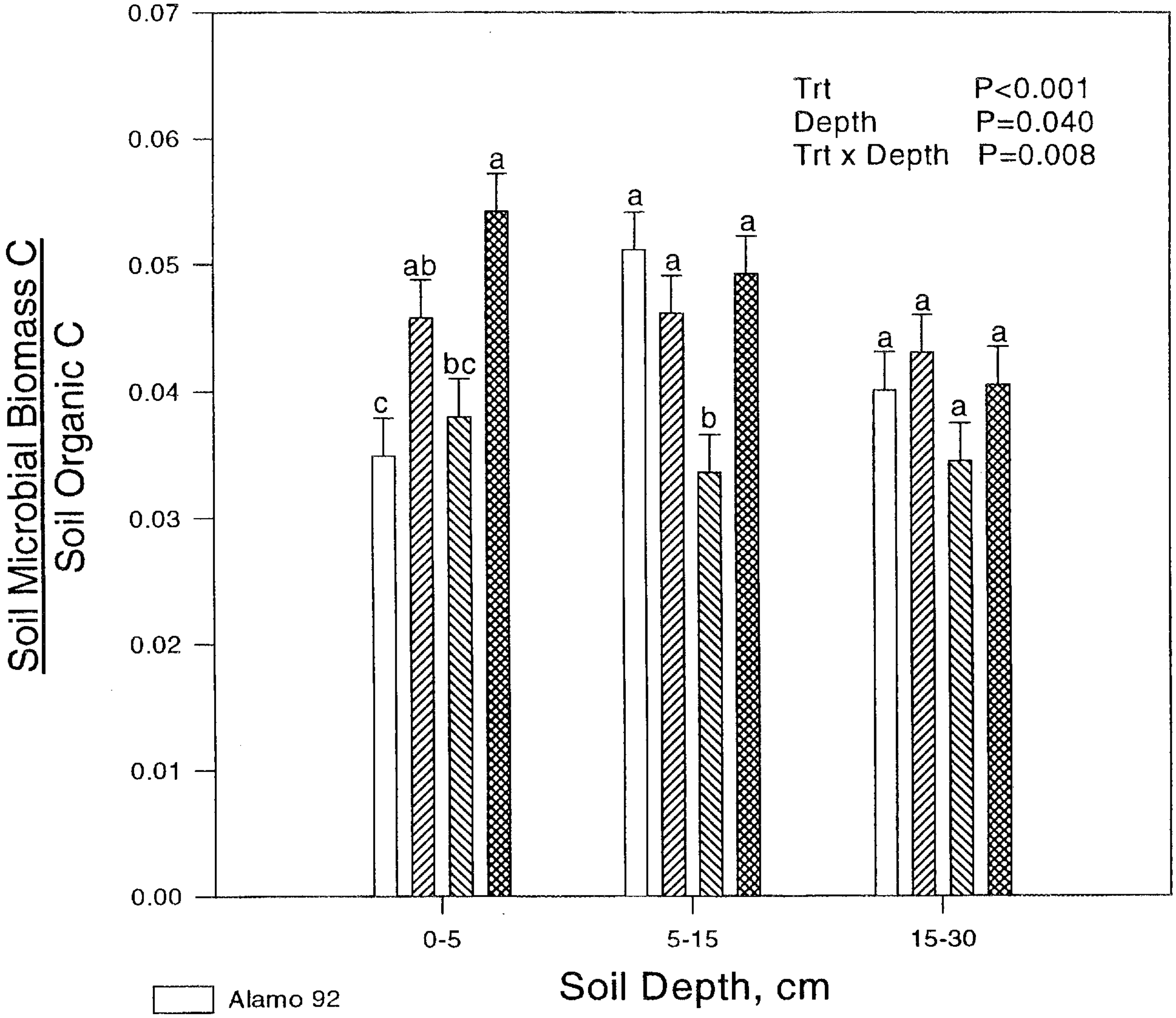
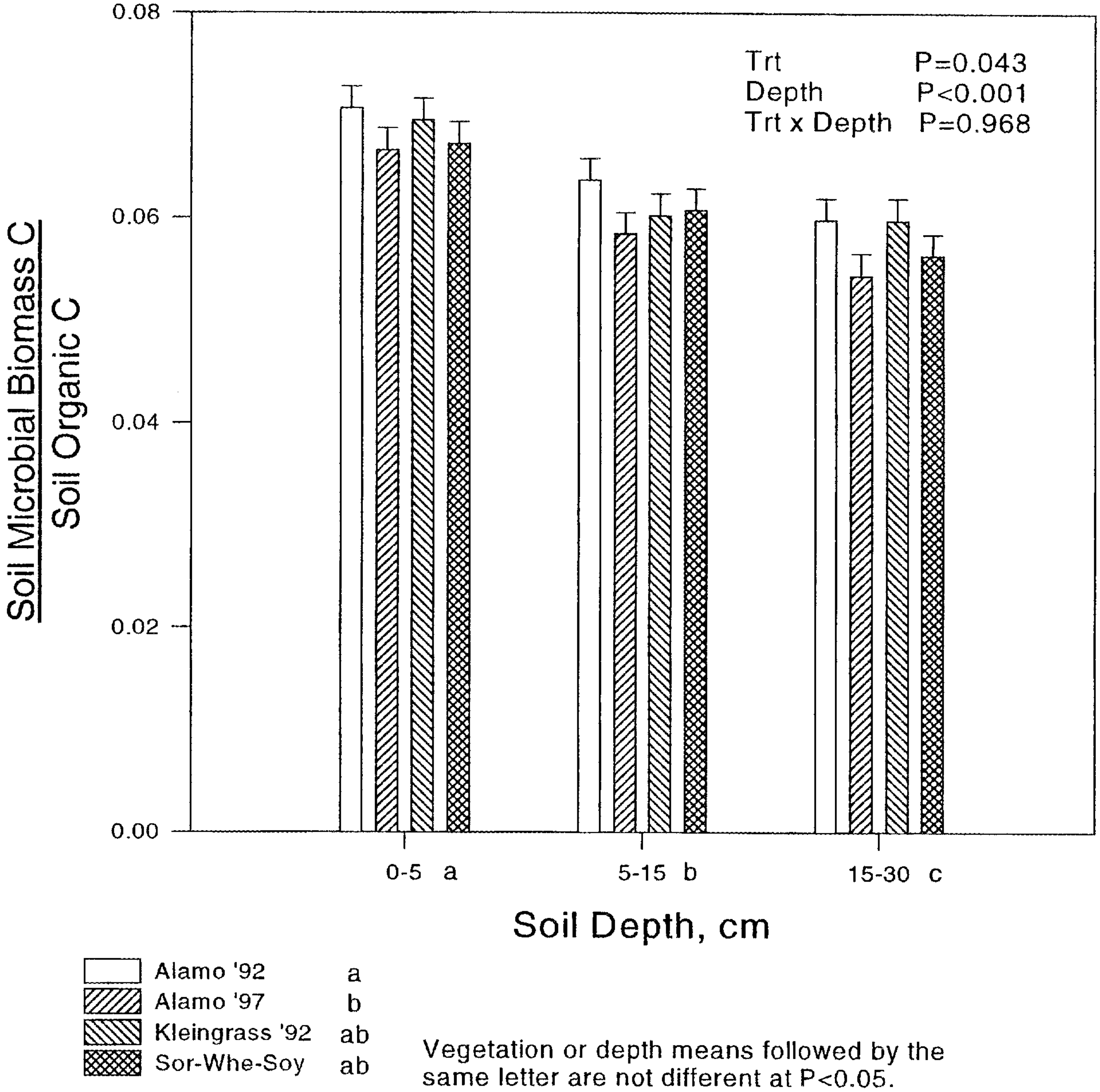


Figure 13
Vegetation and depth effects on the fraction of soil organic carbon as soil microbial biomass carbon - Stephenville, TX, March 2001.



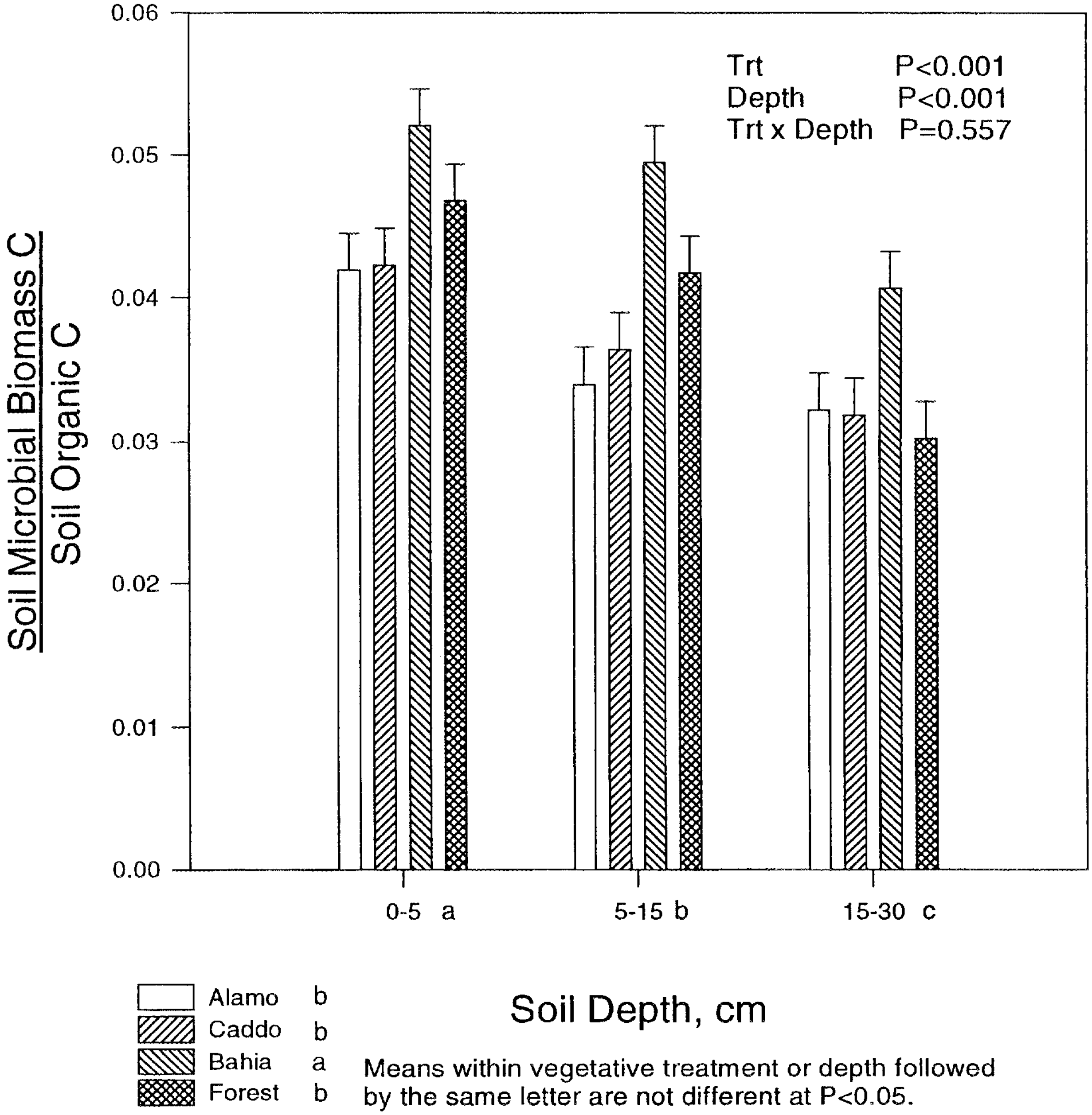
Means within a depth followed by the same letter are not different at P<0.05.

Figure 14
Vegetation and depth effects on the fraction of soil organic carbon as soil microbial biomass carbon - College Station, TX, March 2001.



Vegetation or depth means followed by the same letter are not different at $P<0.05$.

Figure 15
Vegetation and depth effects on the fraction of soil organic carbon as soil microbial biomass carbon - Clinton, LA, March 2001.



Means within vegetative treatment or depth followed by the same letter are not different at $P<0.05$.

Figure 16
Relationship of soil microbial biomass carbon and soil carbon mineralized in 24 days - Dallas, TX, March 2001.

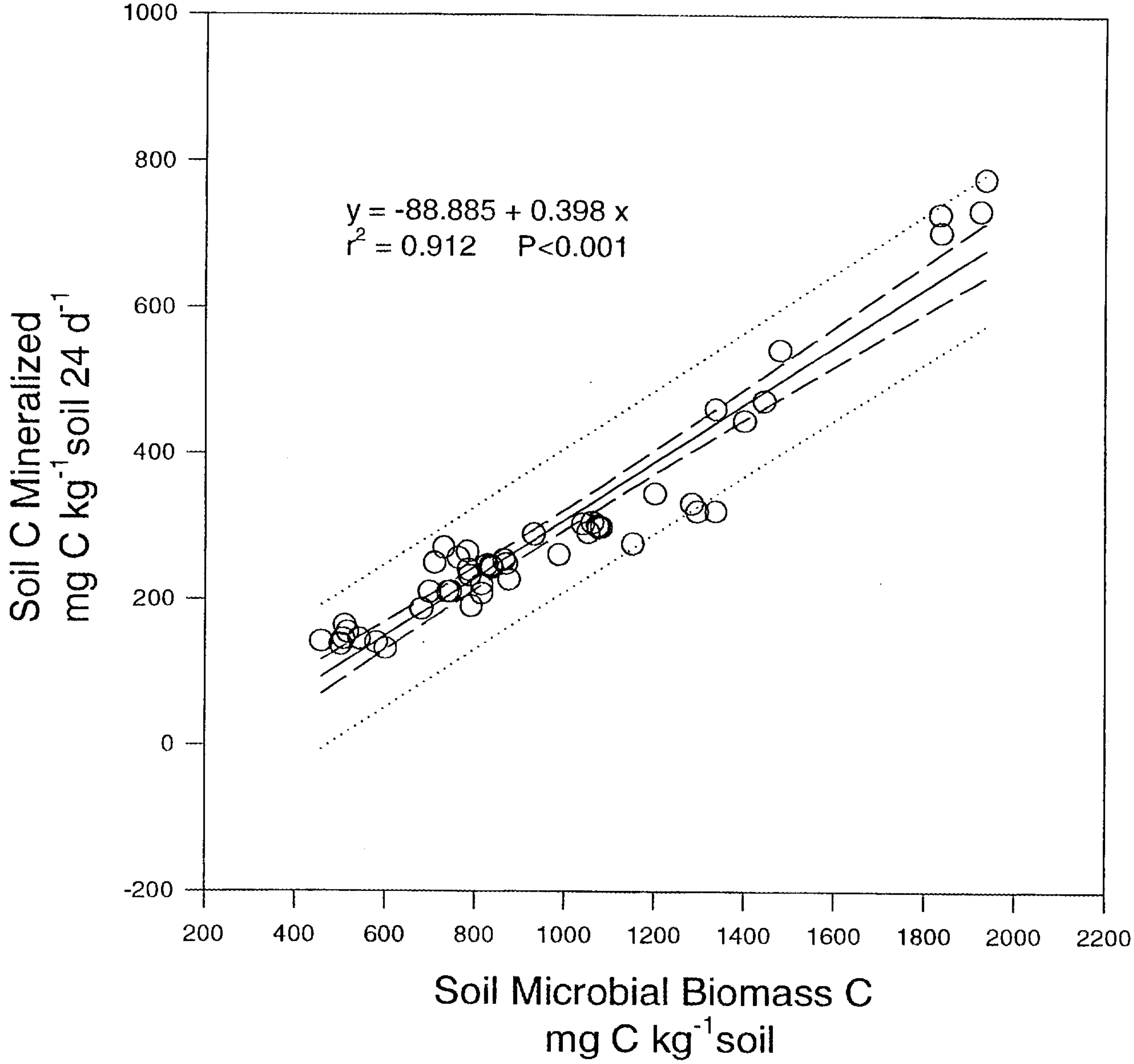


Figure 17
Relationship of vegetation treatment and cumulative soil C mineralized (0-5 cm) - Dallas, TX, March 2001.

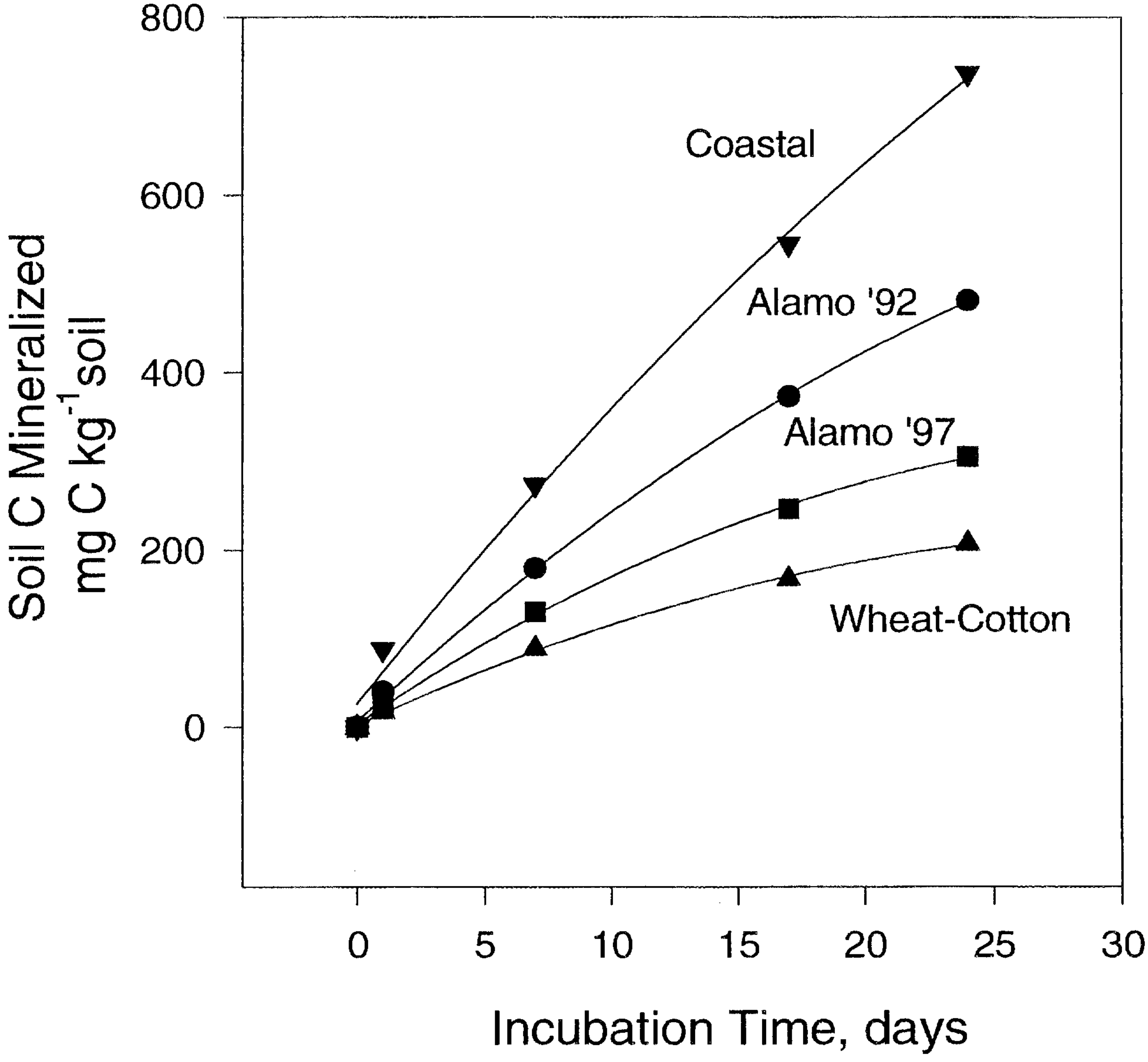


Figure 18
Relationship of vegetation treatment and cumulative soil C mineralized (0-5 cm) - Stephenville, TX, March 2001.

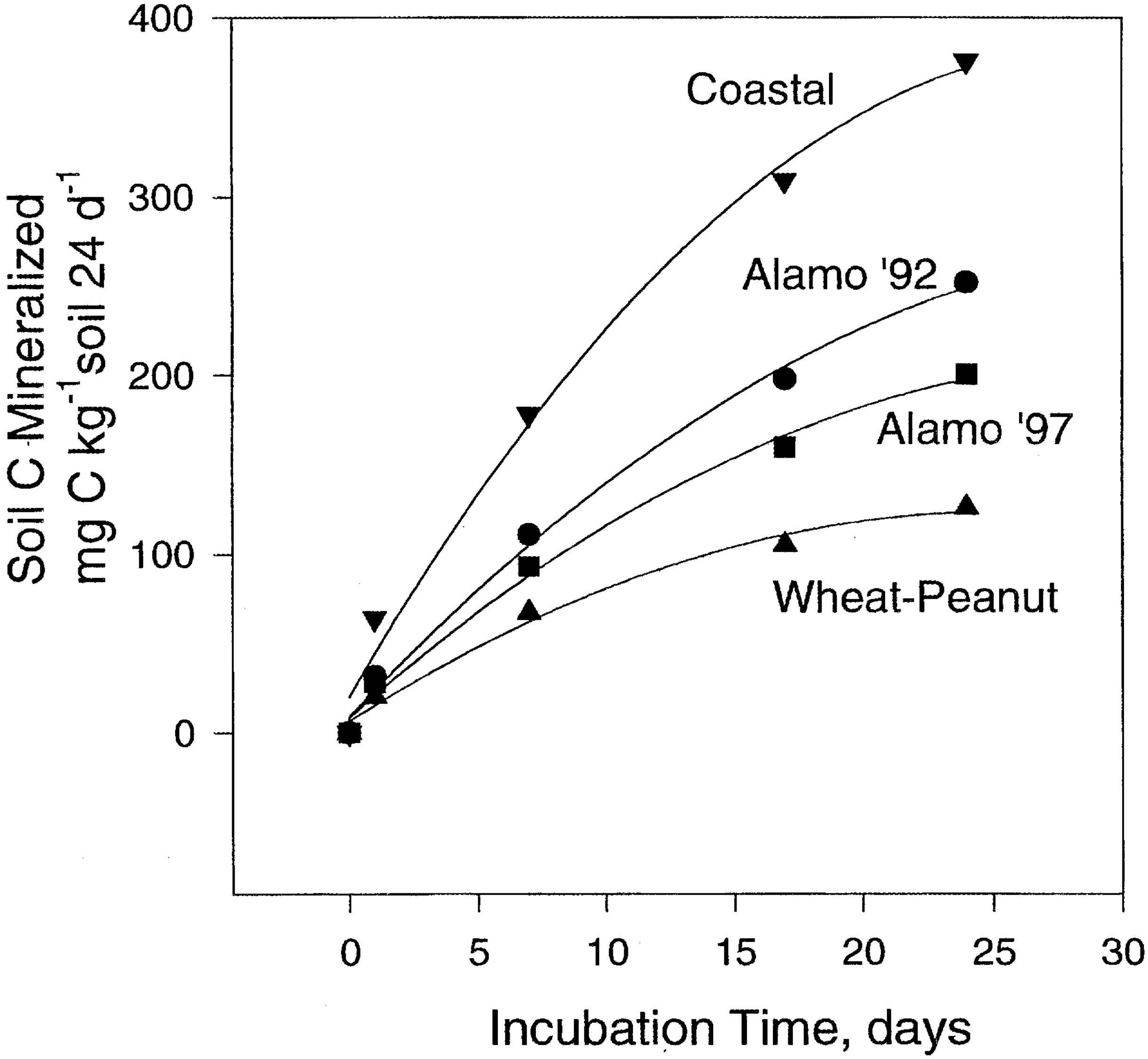


Figure 19
Relationship of vegetation treatment and cumulative soil C mineralized (0-5 cm) - College Station, TX, March 2001.

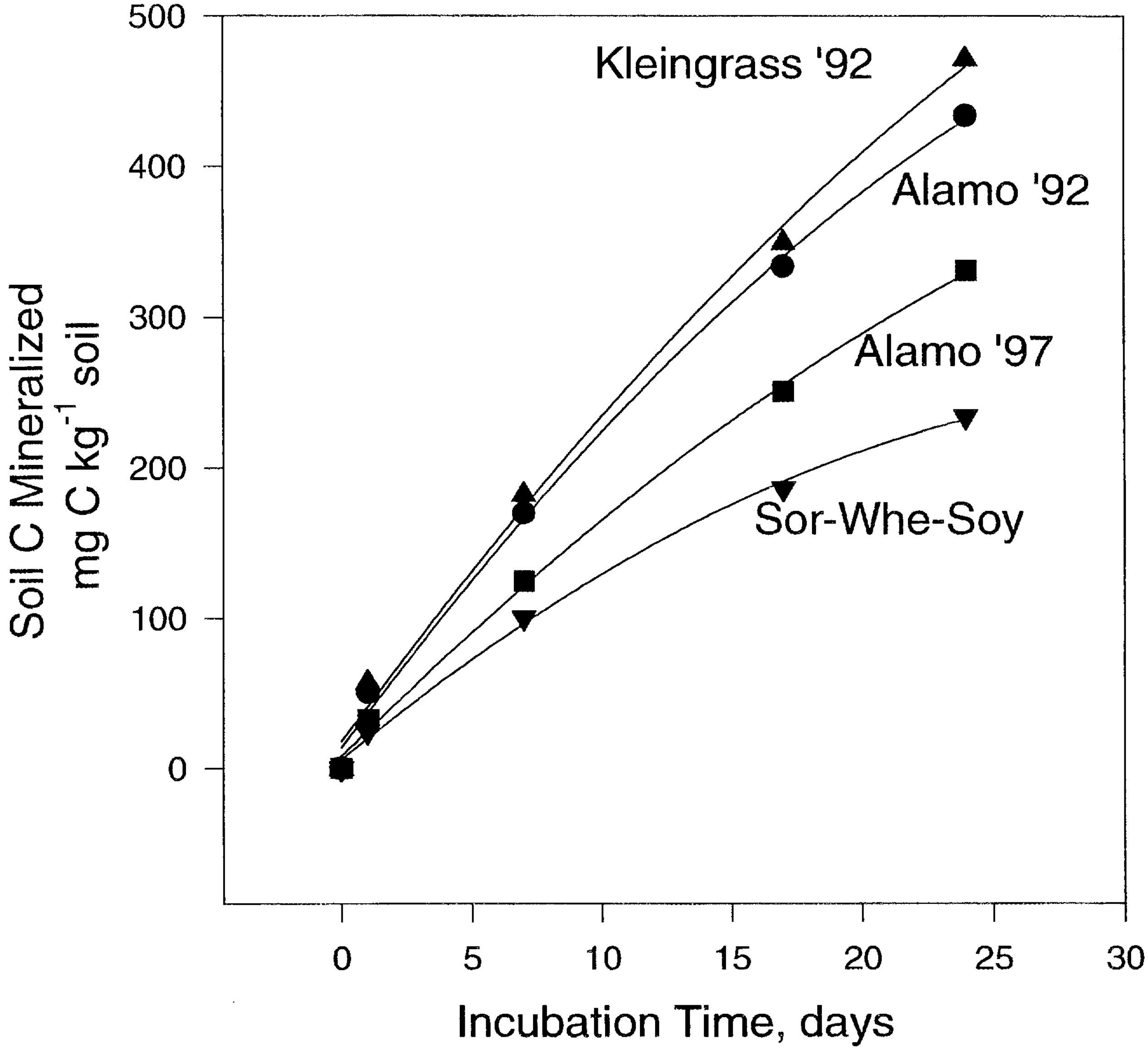


Figure 20
Relationship of vegetation treatment and cumulative soil C mineralized (0-5 cm) - Clinton, LA, March 2001.

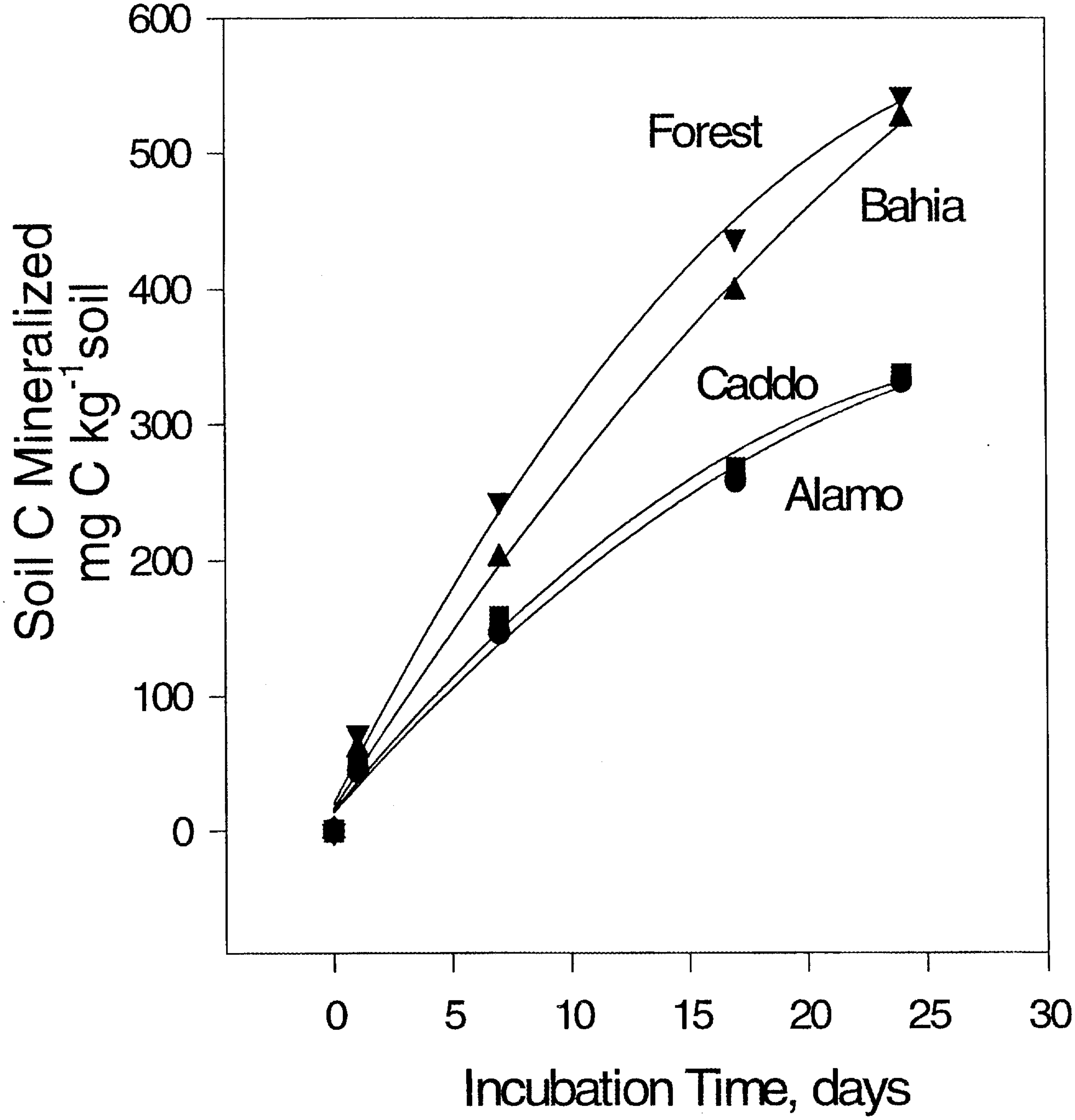
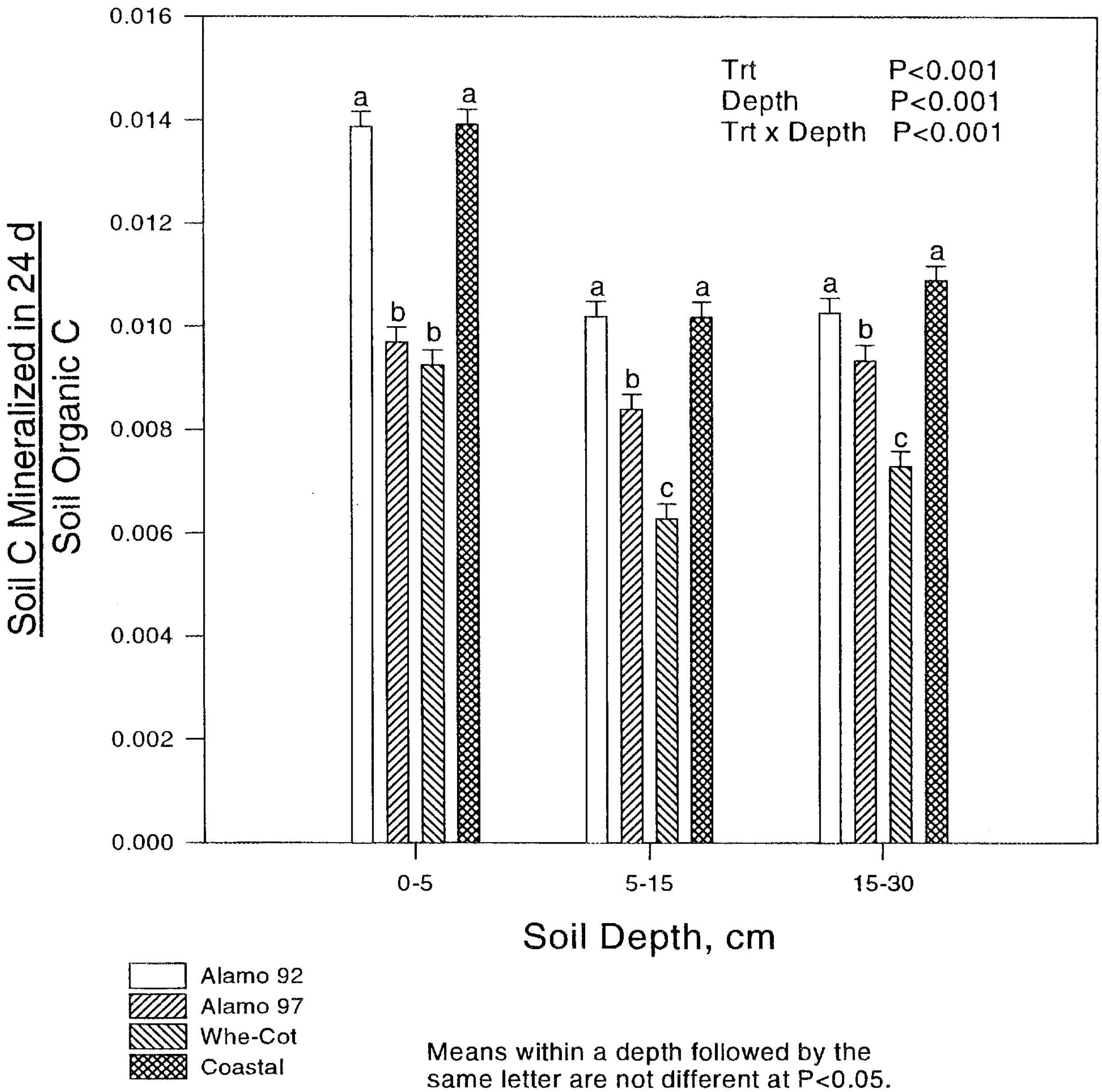


Figure 21
Vegetation and depth effects on the fraction of soil organic carbon mineralized in 24 days - Dallas, TX, March 2001.



Means within a depth followed by the same letter are not different at P<0.05.

Figure 22
Vegetation and depth effects on the fraction of soil organic carbon mineralized in 24 days - Stephenville, TX, March 2001.

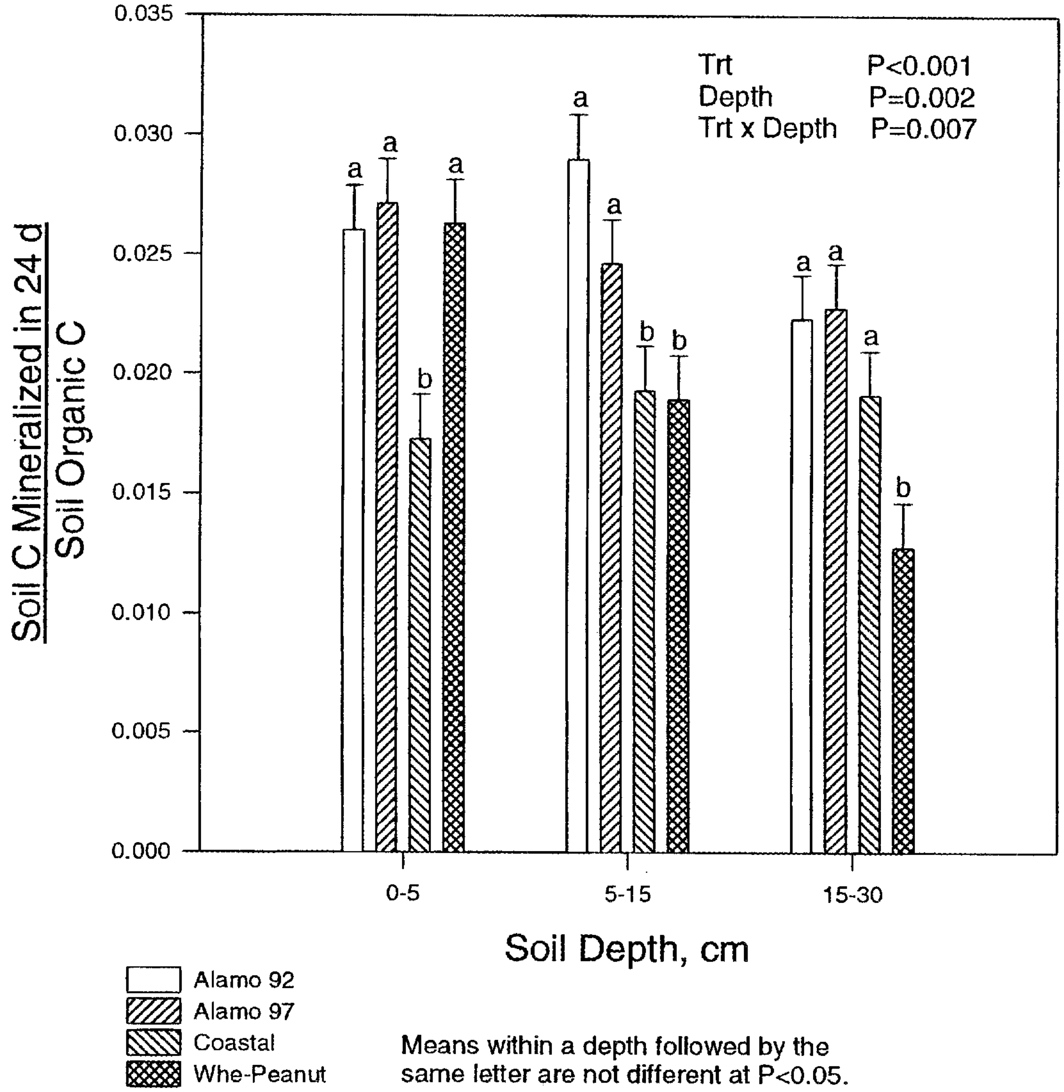


Figure 23
Vegetation and depth effects on the fraction of soil organic carbon mineralized in 24 days - College Station, TX, March 2001.

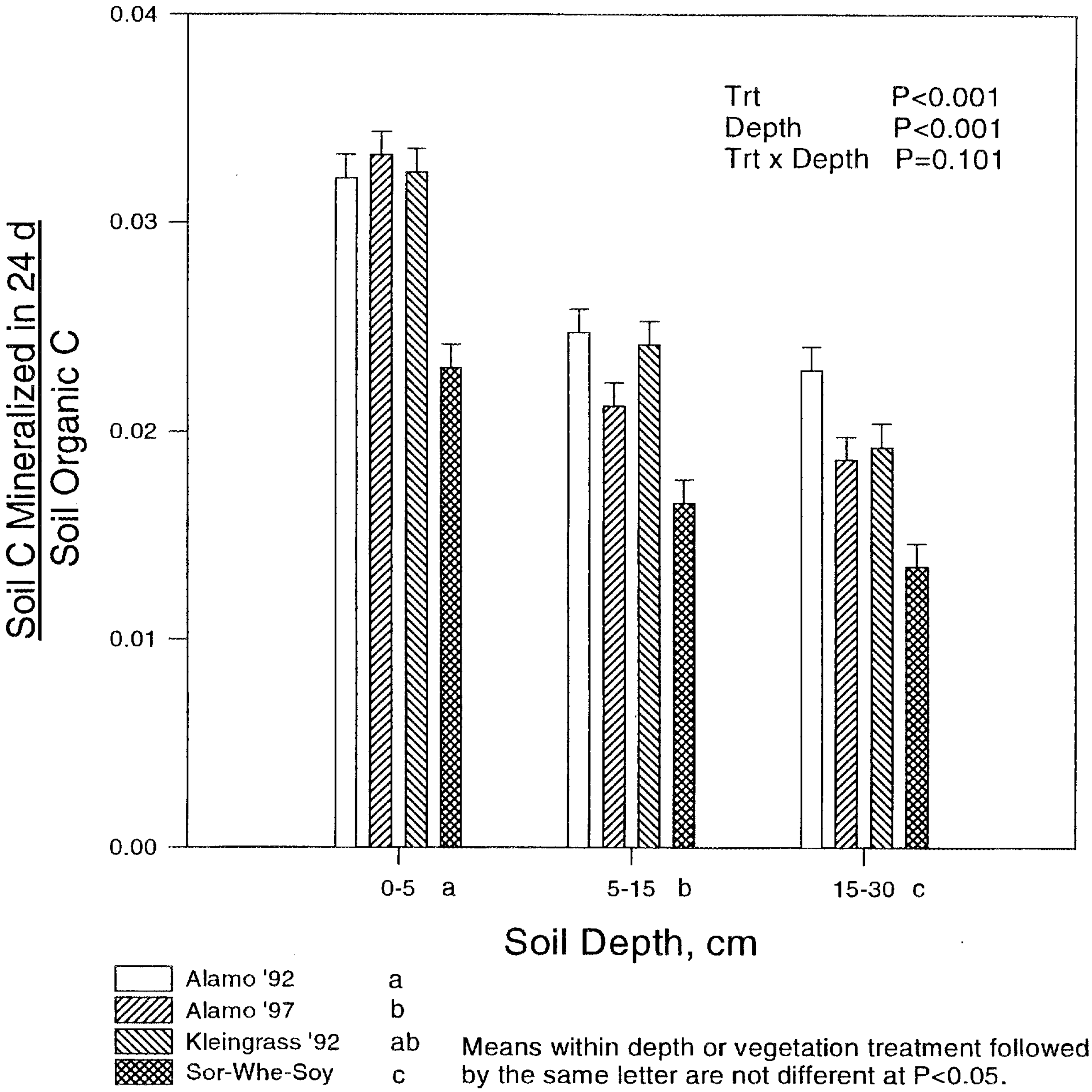
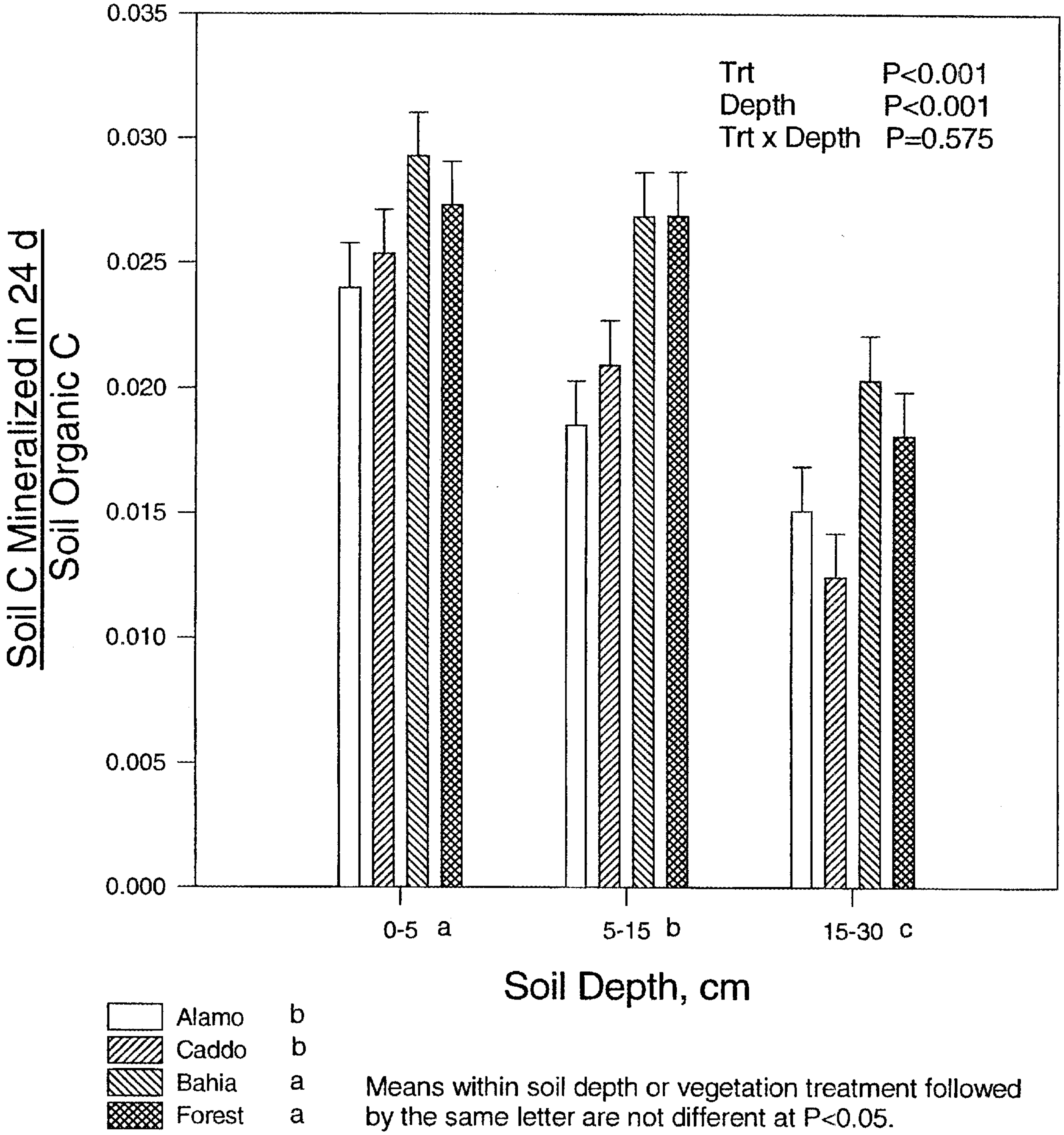


Figure 24
Vegetation and depth effects on the fraction of soil organic carbon mineralized in 24 days - Clinton, LA, March 2001.



Means within soil depth or vegetation treatment followed by the same letter are not different at P<0.05.

Figure 25
Vegetation and depth effects on the fraction of soil organic carbon as particulate organic matter carbon - Dallas, TX, March 2001.

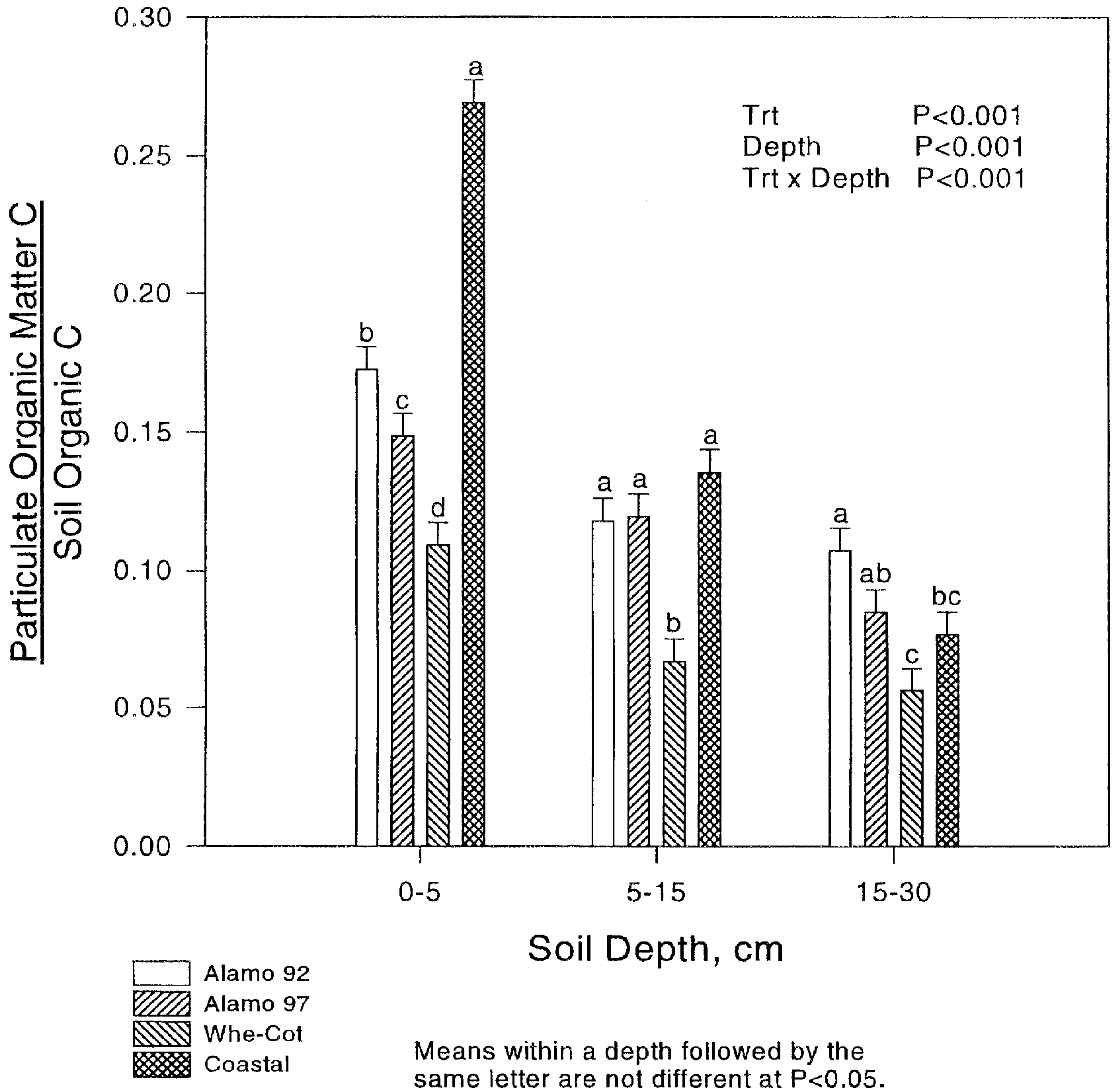


Figure 26
Vegetation and depth effects on the fraction of soil organic carbon as particulate organic matter carbon - Stephenville, TX, March 2001.

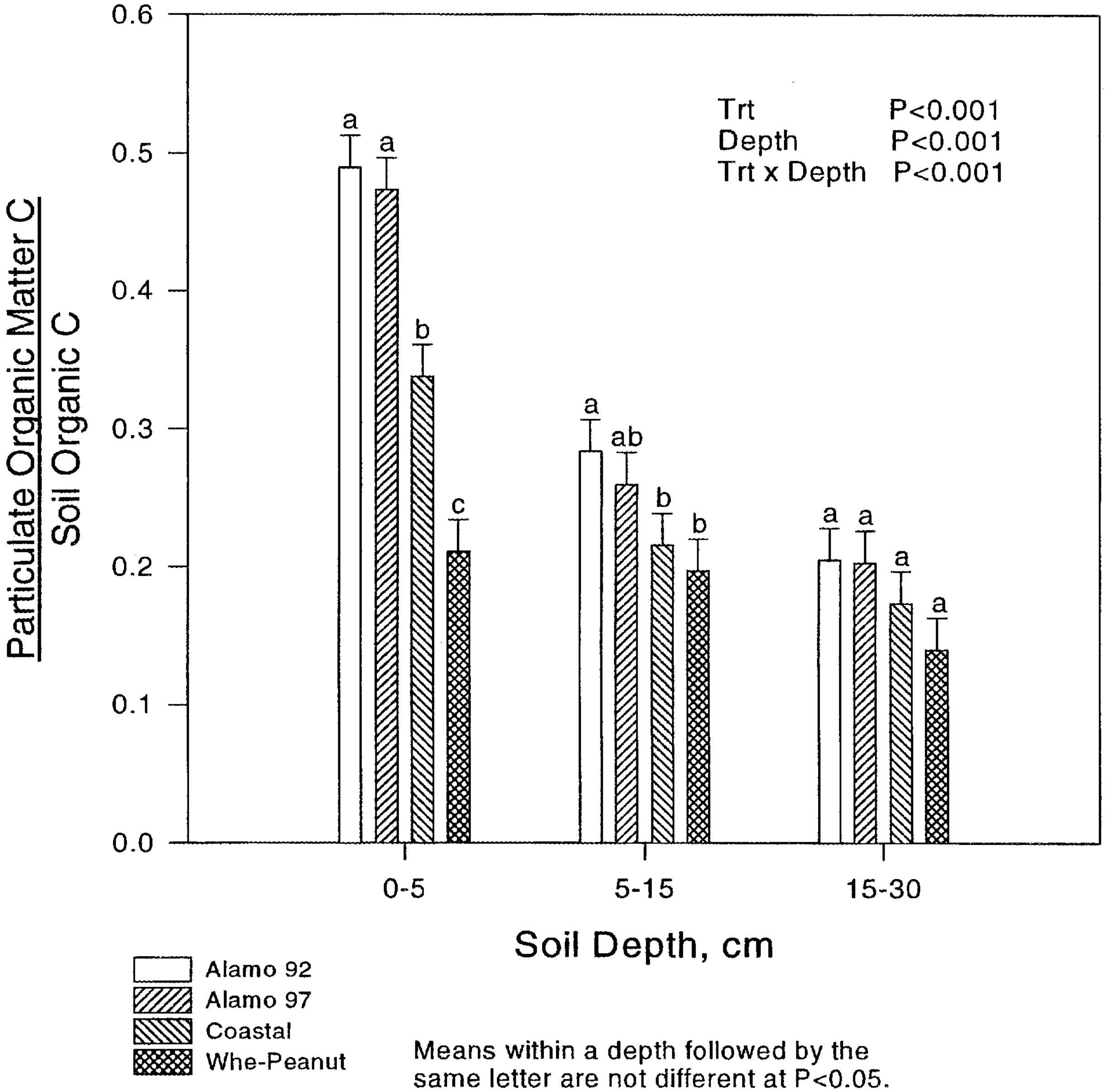


Figure 27
Vegetation and depth effects on the fraction of soil organic carbon as particulate organic matter carbon - College Station, TX, March 2001.

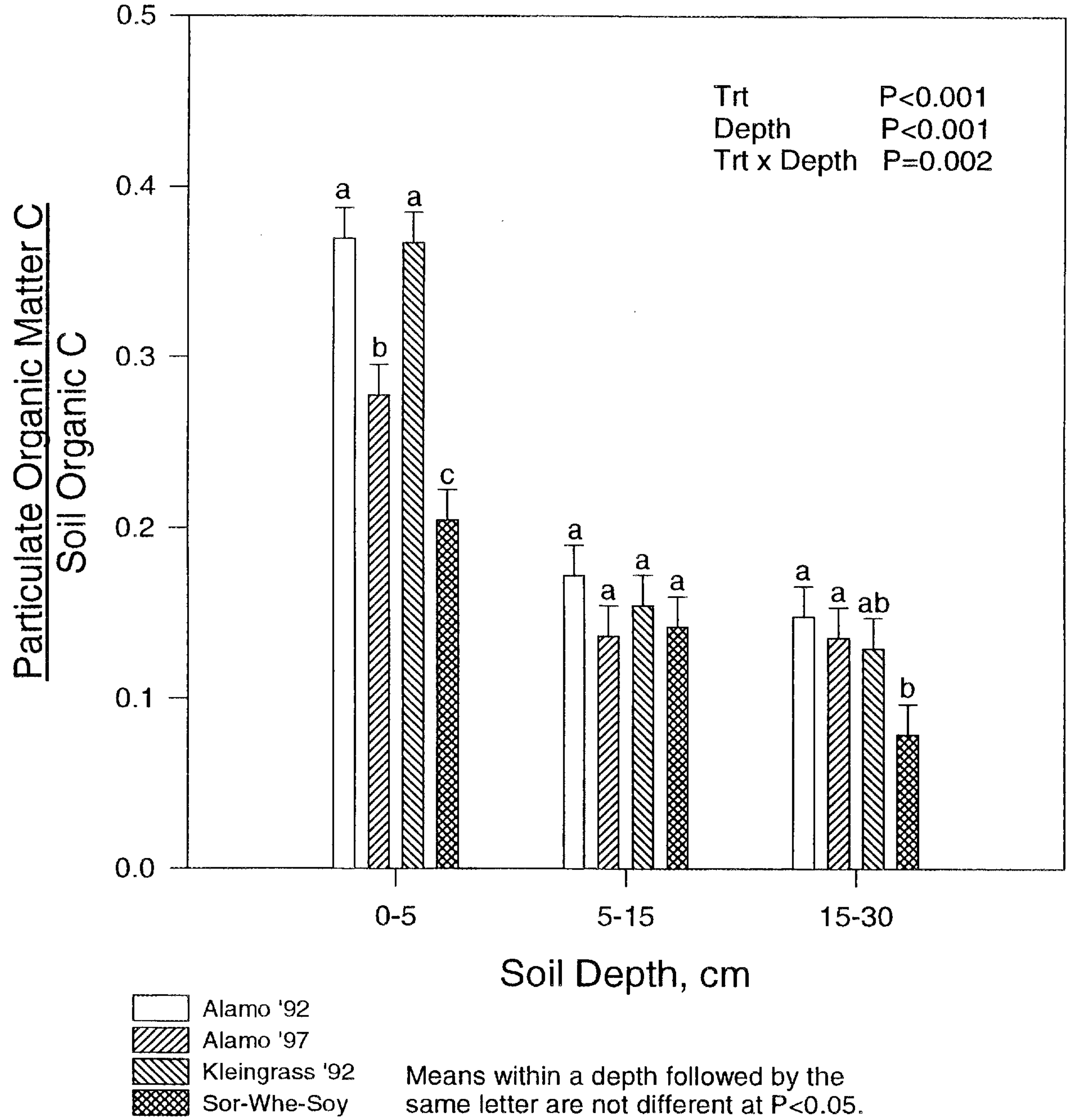
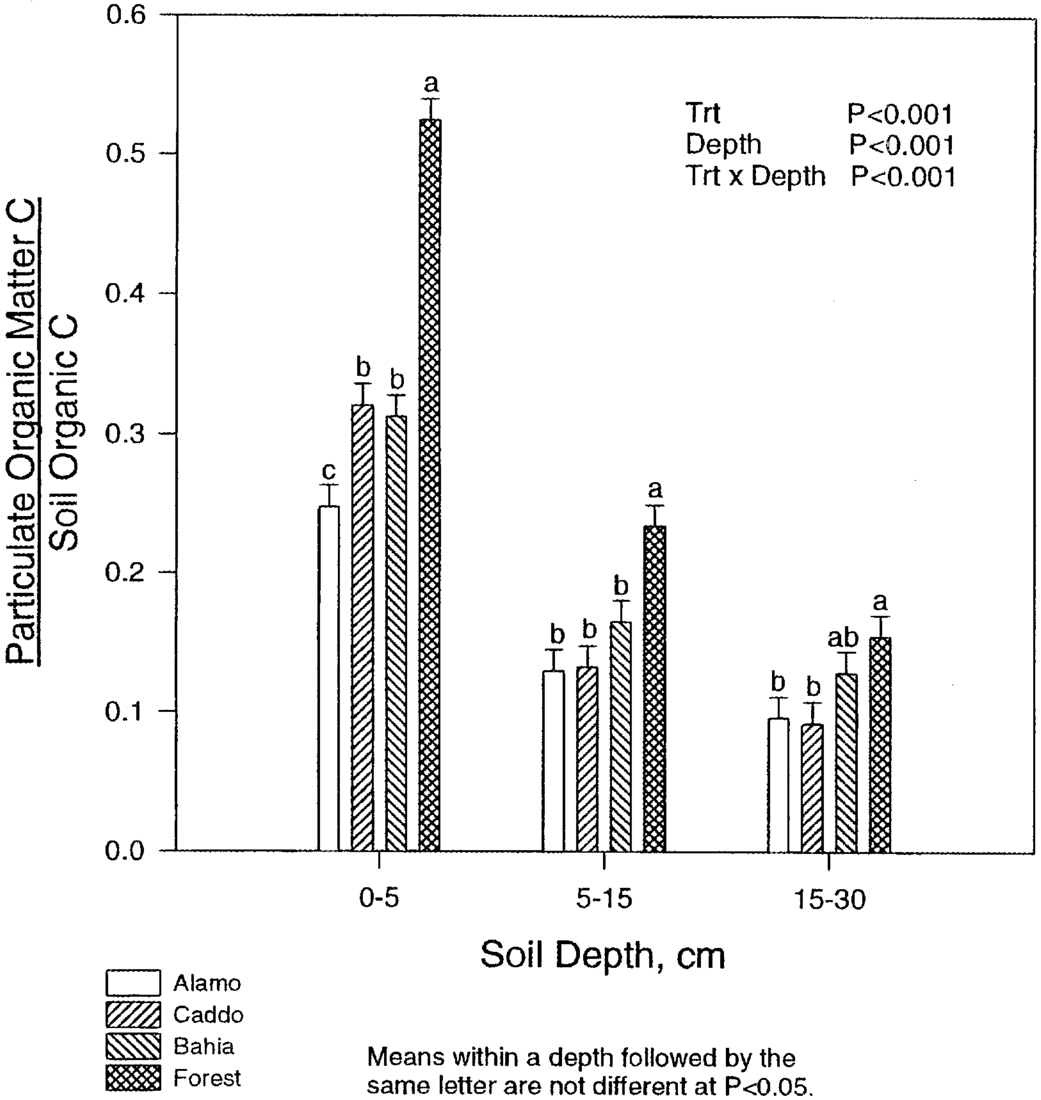


Figure 28
Vegetation and depth effects on the fraction of soil organic carbon as particulate organic matter carbon - Clinton, LA, March 2001.



TASK 3: SWITCHGRASS CULTIVAR AND GERMPLASM EVALUATION

Objectives: 1. Evaluate both upland and lowland ecotypes from the breeding program at OSU (Dr. Charles Taliaferro) compared to the best upland and best lowland cultivar at Stephenville, Dallas, and College Station, TX; Hope, AR; and Clinton, LA. 2. Quantify the long term carbon sequestration trends in all plantings.

Summary of results from 2001 and evaluation of all previous years data for yield and quality attributes are given in the five-year summary report (Section 5). As preliminary data for what we had proposed to do in the next five years, we sampled this set of tests in the fall of 2001 to have a preliminary look at nematode populations. The following is an Abstract of the article that was written (Seed Publications list) to report our findings.

Plant-parasitic nematodes have been suggested as contributors to problems of establishment and persistence in the South Central US, but nematode populations associated with switchgrass have never been described. Plant-parasitic nematodes were identified from both soil and roots of samples collected after fall biomass harvest from five-year-old switchgrass variety trial plots located in Clinton, LA, Hope, AR, College Station, TX, and Stephenville, TX. *Xiphenema americanum* and *Tylenchorhynchus* spp. (*T. capitatus* and *T. ewingi*) were found at all locations. *Paratrichodorus minor* and *Criconemella ornata* were found in three of four sites. *Hoplolaimus magnistylus, Pratylenchus zeae*, *Helicotylenchus* spp. (H. *dihystera* and H. *digonius*), *Meloidogyne* sp., and *Paratylencus* sp. were identified from some sites. Upland morphological types of switchgrass supported greater densities of *Helicotylenchus* spp. than lowland types at Clinton and greater densities of *Pratylenchus* and *Tylenchorhynchus* spp. at Hope. Lowland types appeared to be better hosts for *Tylenchorhynchus* spp. at Stephenville. Differences in host suitability among switchgrass genotypes were found for several nematode species, and in some cases the nematodes were correlated with decreased stand persistence or dry matter yield.

TASK 4: SWITCHGRASS NITROGEN-PHOSPHOROUS ROW-SPACING STUDY (Terminated in 2000 and published. See Section 5 and Publications Section (Section 4).

TASK 5: FACTORS INFLUENCING SWITCHGRASS ESTABLISHMENT

Objectives: 1. Determine in a series of small plot trials the Best Management Practices necessary to improve the reliability of establishing a stand of switchgrass.

2. Conduct controlled environment studies to develop Science-Based knowledge regarding switchgrass stand establishment. 3. Select for specific plant traits that are thought to control seedling success.

Herbicide Screening

Using Activated Carbon as a Herbicide Safener for Switchgrass Establishment

Introduction. The activated carbon technology is common in the grass seed industry in Oregon to aid in establishment and has worked quite well over the years. A greenhouse study was initiated to determine if the concept could possibly aid in switchgrass establishment.

Material and Methods. Herbicides that had shown promise in field studies for weed control and switchgrass establishment were selected for a greenhouse study to evaluate the safening effects of activated carbon when using herbicides on switchgrass seedlings. Switchgrass seeds (100 seed by weight/row) were planted 1.5 cm deep in trays on 27 March. One day later, activated carbon (mixed at rate of 370 kg per 122 L/ha) was sprayed with in a 3.8 cm band over each row of planted switchgrass. Comparison trays were set up without application of carbon strips. Herbicides were mixed and applied with a CO_2 backpack sprayer at 187 L/ha over each tray. Seedling counts (no/15 cm of row) and plant height measurements were taken, 13, 22, 30,

and 37 days after planting (DAP). Plants were harvested (15 cm of row) 45 DAP and air dried for 72 hr prior to weighing.

The experimental design was a randomized complete block replicated three times in a factorial arrangement of treatments. Herbicides and carbon/no carbon were factors. An untreated check (w/wo carbon) was included for comparison.

Results and Discussion. Plant numbers in the untreated check varied from 24.0 to 26.3 (with carbon) and 25.0 to 27.7 (without carbon). Switchgrass populations were improved when the activated carbon was used with Paramount, First Rate, or Paramount + Atrazine combinations (Table 5-1). Switchgrass populations were not improved when activated carbon was used in combination with Atrazine alone at either rate.

Switchgrass plant heights were slightly improved when activated carbon was applied over switchgrass seed without any herbicides. Significant increases in switchgrass plant heights were noted when the activated carbon band was applied prior to the application of all herbicides (Table 5-1).

Switchgrass plant dry weights were not improved when activated carbon was used in combination with Paramount at 0.28 kg/ha, or Atrazine at either rate. Significant increases in plant dry weights were noted with the activated carbon when applied with Paramount at 0.56 kg/ha, First Rate at 0.02 and 0.04 kg/ha, and the combination of Paramount + Atrazine.

These results correlate well with our field studies which have shown a rate response with Paramount and Paramount + Atrazine mixtures. Doubling the rate of these two herbicides resulted in a 55 and 24% reduction in switchgrass forage dry weights in 2001 field studies. Doubling the rate of Atrazine increased switchgrass yield by 250% while increasing the rate of First Rate resulted in virtually no yield increase in our field studies.

Studies in the Midwest have also reported that Atrazine and Paramount are safe on switchgrass. Using activate carbon in combination with herbicides may allow producers to use herbicides which may eliminate severe weed pressure while having no effect on switchgrass. Additional greenhouse and field studies need to be conducted to further study herbicides/activated carbon interactions.

Table 5-1. Switchgrass seedling response to herbicides with/without an activated carbon applied over the seeded row.

Treatment	Rate kg/ha	No. Plant/6" row 13 DAP	22 DAP	30 DAP	37 DAP	Plant Ht (cm) 22 DAP	30 DAP	37 DAP	Dry Wt (gr)
Check	-								
with carbon	-	24.7	26.0	26.3	24.0	8.2	12.3	19.0	0.680
w/o	-	27.7	25.0	27.3	26.3	7.2	11.0	15.0	0.481
Paramount	0.28								
with carbon		24.7	22.7	24.7	21.7	5.2	6.3	8.7	0.145
w/o		22.3	18.7	20.0	13.0	1.2	1.8	2.2	0.216
Paramount	0.56								
with carbon		23.0	21.7	22.0	17.7	4.5	6.3	10.5	0.477
w/o		24.7	16.0	16.0	5.3	0.8	1.2	1.2	0
Atrazine	1.12								
with carbon		25.0	24.7	24.7	24.0	6.5	8.3	12.5	0.536
w/o		27.0	24.7	25.7	24.0	3.5	4.2	9.3	0.415
Atrazine	2.24								
with carbon		19.7	20.3	21.3	20.0	5.7	10.2	16.3	0.792
w/o		23.7	24.3	25.0	24.7	5.0	8.5	12.2	0.552
First Rate	0.02								
with carbon		29.0	29.7	30.3	28.0	7.0	8.8	15.0	0.720
w/o		26.0	23.7	24.3	22.7	3.7	4.0	5.0	0.211
First Rate	0.04								
with carbon		23.3	24.0	25.0	23.0	6.0	8.3	13.3	0.538
w/o		25.0	23.7	24.3	22.7	3.3	3.8	4.5	0.127
Paramount + Atrazine	0.28 + 1.12								
with carbon		23.3	24.0	24.3	23.7	7.2	11.3	14.7	0.740
w/o		30.0	18.0	17.7	8.0	1.5	2.2	3.2	0.006
Paramount + Atrazine	0.56 + 2.24								
with carbon		22.3	22.7	23.3	22.7	6.8	9.0	16.3	0.650
w/o		25.3	23.0	22.0	18.3	2.5	4.0	4.8	0.183
LSD (0.05)		6.8	7.3	6.9	5.9	1.9	3.8	5.9	0.396

Switchgrass-Herbicide Field Screening

Introduction. Field studies were completed in the spring of 2002 dealing with switchgrass tolerance to various soil applied herbicides. Switchgrass establishment is a problem in many areas of the southwest due to competition from broadleaf weeds and annual grasses. Establishment may be made easier if competition from these weeds is reduced or eliminated without injury to switchgrass. The use of herbicides can be an important tool that is used to meet this goal.

Material and Methods. A field study was begun in the spring of 2001 in an area with moderate annual grass pressure to evaluate various soil-applied herbicides for switchgrass tolerance. "Alamo" switchgrass was planted 1.3 cm deep on April 27 in a Denhawken fine sandy loam with < 1% organic matter and a pH of 7.2. Preemergence (PRE) herbicides were applied one day after planting (April 28). Herbicides were applied in water with a CO_2 backpack sprayer using Teejet 11002 flat fan nozzles which delivered a spray volume of 190 L/ha at 180 kPa. Visual ratings of switchgrass stands were recorded approximately 6 wk after planting. Plant height measurements were also recorded on the same date. Five plants per plot were selected at random and measurements were made from the ground line to tip of plant growth. Switchgrass was cut for yield on March 13, 2002. Sites were selected at random within a plot and 61 cm x 61 cm areas were hand clipped, dried, and dry weights recorded. Switchgrass yields were then calculated on a per acre basis.

Results and Discussion. The untreated check had approximately 20% switchgrass stand while Dual Magnum at 1.12 kg/ha, Prowl, Zorial, Caparol, Cotoran, Valor at 0.07 kg/ha, Python at 1.0 oz/A and Cadre at 0.07 kg/ha resulted in < 10% switchgrass stand establishment (Table 5-2). First Rate at 0.3 oz/A, Paramount at 0.28 kg/ha, and Atrazine at 1.12 kg/ha plus Paramount at 0.28 kg/ha resulted in > 30% stand establishment.

Little differences were noted in switchgrass plant height when measured approximately 6 wk after planting. Paramount at 0.28 kg/ha treated plots had the tallest plants while Prowl and Cotoran at 1.12 kg/ha showed the least switchgrass growth.

Switchgrass yields were variable due to inconsistent stand establishment (Table 5-2). Dual Magnum at 1.12 kg/ha and Prowl resulted in no harvestable yield while the untreated check, Paramount at 0.28 kg/ha, and atrazine + Paramount mixtures resulted in yields of > 1500 kg/ha dry matter. High yields obtained in the untreated check indicated that weed competition may not be an important factor in switchgrass establishment in areas with low to moderate weed pressure.

Table 5-2. Effects of soil applied herbicides on switchgrass stand and growth.

Treatment yield	Rate kg/ha	Canopy stand %	Plant ht. cm	kg/ha
Check	-	21	69.3	3539
Dual Magnum	0.56	20	75.7	535
Dual Magnum	1.12	3	73.7	0
Strongarm	0.02	11	79.8	961
Strongarm	0.03	28	88.1	1301
Prowl	0.84	2	56.9	0
Zorial	0.45	8	81.5	907
Caparol	1.12	7	72.6	1197
Caparol	1.68	7	81.5	383
Cotoran	1.12	3	69.3	610
Cotoran	1.68	5	83.6	427
Atrazine	1.12	15	75.2	580
Atrazine	2.24	19	80.3	1473
Frontier	0.84	19	83.3	851
Frontier	1.40	22	80.0	1325
Valor	0.04	29	84.1	1393
Valor	0.07	9	73.4	863
First Rate	0.02	32	71.4	1128
First Rate	0.04	20	75.2	1366
Python	0.03	20	72.4	1079
Python	0.06	9	77.7	1135
Paramount	0.28	37	96.3	2551
Paramount	0.56	13	80.8	1135
Atrazine + Paramount	1.12 + 0.28	34	91.7	2223
Atrazine + Paramount	1.12 + 0.56	19	83.3	1687
Cadre	0.04	24	83.3	1378
Cadre	0.07	5	78.7	195
LSD (0.05)		29	17.4	2020

Soil Type and Moisture Level Influence on Alamo Switchgrass Emergence and Seedling Growth

Background. As with most warm-season perennial grasses, switchgrass establishment is difficult because of erratic seed germination and poor seedling growth. Because of poor emergence, weed competition is also a major problem. More risk is associated with establishment on sandy Coastal Plain soils because of their low water holding capacity and rapid drying of the soil surface after a rainfall event. There is no information on how emergence might differ on various soils or what the critical rainfall interval is for seedling survival.

A greenhouse study was conducted to determine the influence of soil series and moisture level on "Alamo" switchgrass emergence and seedling growth. Soils used were Bowie very fine sandy loam and Darco loamy fine sand, which are upland Coastal Plain soils from near Overton in Rusk County. Weswood silt loam is a Brazos River bottom soil collected south of College Station in Burleson County. The Houston Black clay is an upland soil from Temple in Bell County. Soils were put in plastic pots (5 in. wide x 5 in. tall) and placed in the greenhouse. Twelve seed of Alamo switchgrass were placed on the soil surface of each pot and covered with a ½ in. of soil. Pots were watered every 3-4, 7, 10-11, or 14 days. Emergence was recorded daily for the first 28 days and seedlings removed at 6 weeks to compare seedling traits. The study was initiated on March 30, 2001 and repeated on May 29 and July 24.

Research Findings. The Bowie very fine sandy loam and the Darco loamy fine sand had similar soil moisture levels (Fig. 1). Moisture levels were frequently near 0% at the 10- and 14-day watering intervals with maximum moisture levels of 10 to 15% at the 3-day watering interval. Moisture levels in the Weswood silty loam were never below 5% with maximum levels from 20 to 25% at the 3-day watering interval. The Houston clay had the greatest moisture retention with minimum soil moisture levels at approximately 10% with levels up to 30% for the 3-day watering interval.

There were not any consistent differences among soil series for switchgrass emergence (Fig. 2). There was a tendency for switchgrass to have greater and more rapid emergence when watered at least every 7 days, especially under the high temperatures during the July 24 run (Fig. 3). Seedling survival was always good in the Houston Black clay regardless of watering interval because of its high moisture holding capacity. Seedling survival decreased rapidly in the Darco loamy fine sand and Weswood silty loam when watered only every 10 or 14 days (Fig. 4). A watering interval of 7 days or less was necessary for seedling survival of 90% or more in all soils.

The general trend was for seedling development to be more advanced and shoot and root weights to be heavier in the two sandier soils than in the Weswood silt loam and Houston clay soils if the seedlings survived (Fig. 5). The Weswood silt loam cracked vary badly, especially at the 10- and 14-day watering interval, which limited seedling growth. Differences in shoot stage among soil types only occurred at the 10- and 14-day watering intervals. Shoot weight differences among soil types were more pronounced than for shoot stage. There was a general decline in shoot weight as the watering interval increased for all runs. Shoot weight differences occurred among soils at each watering interval for every date. The highest shoot weight was in the Darco loam fine sand and lowest in the Weswood and Houston soils.

There was a general decline in root development as watering interval increased (Fig. 5). If watered every 3 days, there were no differences among soil series. If the seedlings survived, root stage was more advanced in the sandier soils than in the loam and clay soils. The trends in root weight were identical to that of shoot weight with differences among soil series at every watering interval. As with the other seedling traits, there was a general decline in root weight as watering interval increased, especially at the higher temperatures in the July 24 run. Root weights were always greater in the Darco soil and usually in the Bowie soil if the seedlings survived. There was an interaction between soil types and watering interval for root/shoot ratio (Fig. 6).

Conclusions. The Darco and Bowie soils are representative of most soils found in East Texas. Switchgrass seedling growth and development was good in these soils, but it was very critical that the seedlings received water every 7 to 10 days. Switchgrass should be planted from late April through mid-May when temperatures are mild and rain chances are good. Necessary rainfall at least every 10 days is one of the factors for unreliable switchgrass establishment on sandy soils in the Lower South.

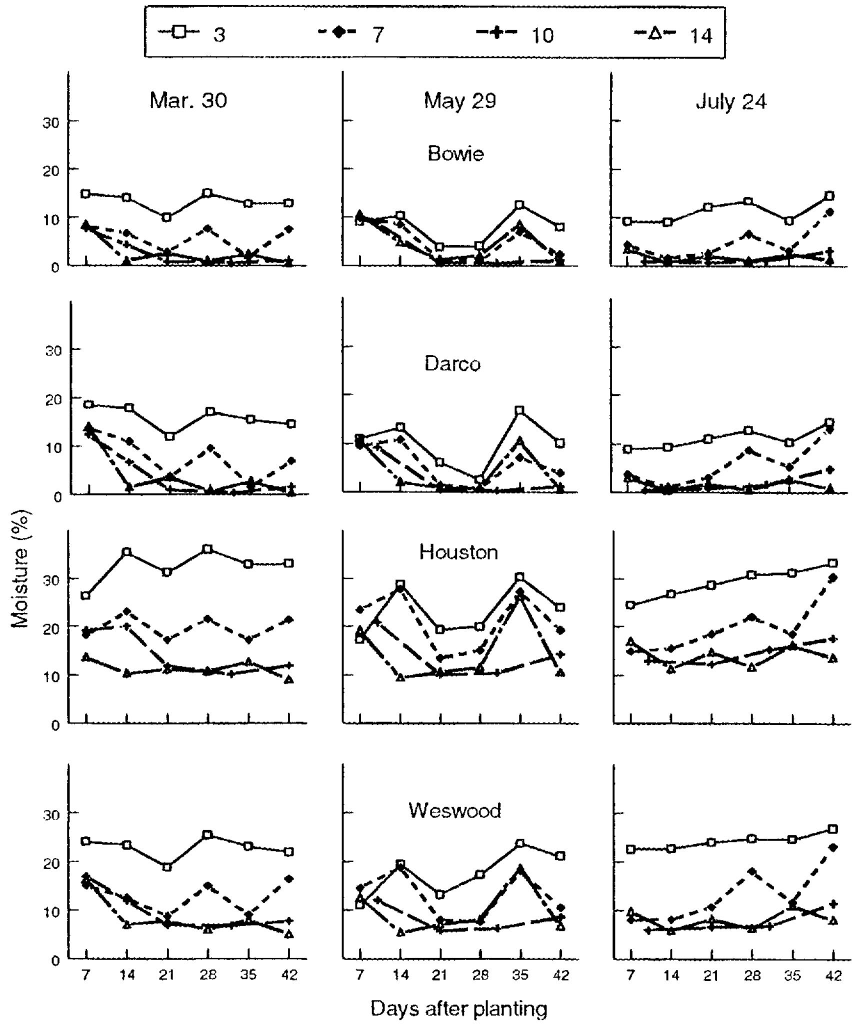


Fig. 1. Soil moisture levels of four soil series at four watering intervals for three dates.

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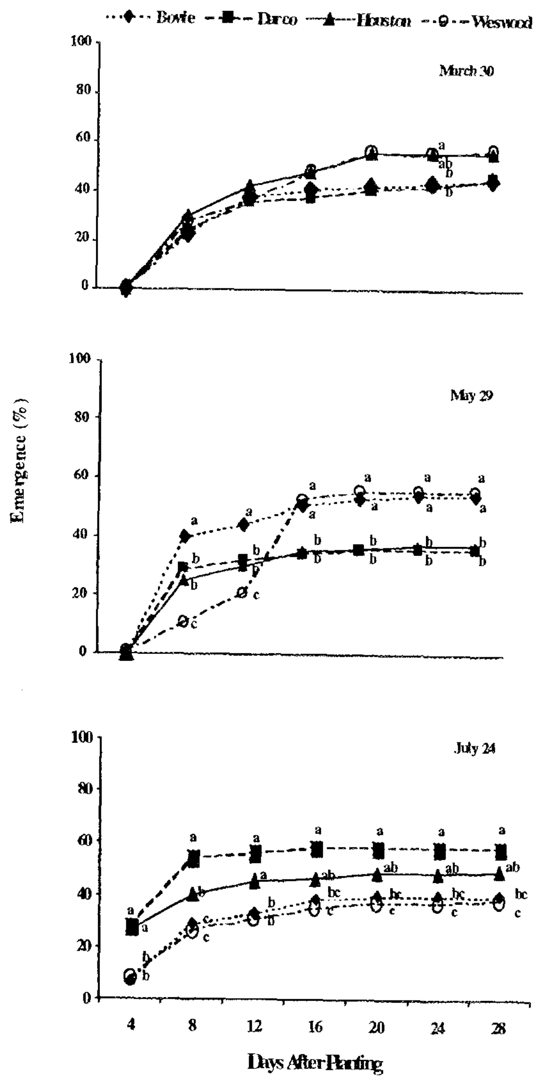

Figure 2. Switchgrass emergence in four soil series averaged across watering intervals at three dates.

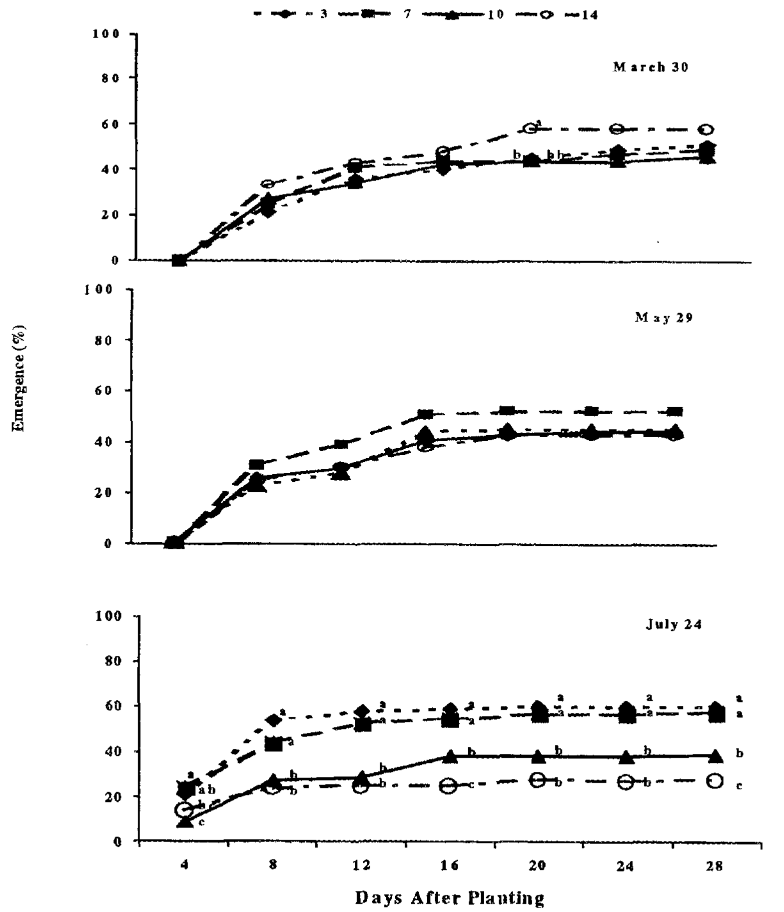

Fig. 3. Switchgrass emergence at four watering intervals averaged across soil series at three dates.

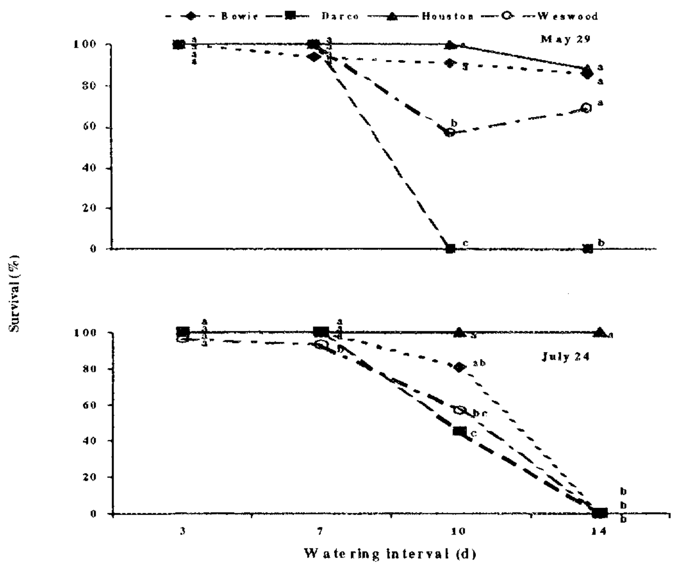

Fig. 4. Interaction of soil series and watering interval on percent survival of emerged seedlings for the May 28 and July 24 dates.

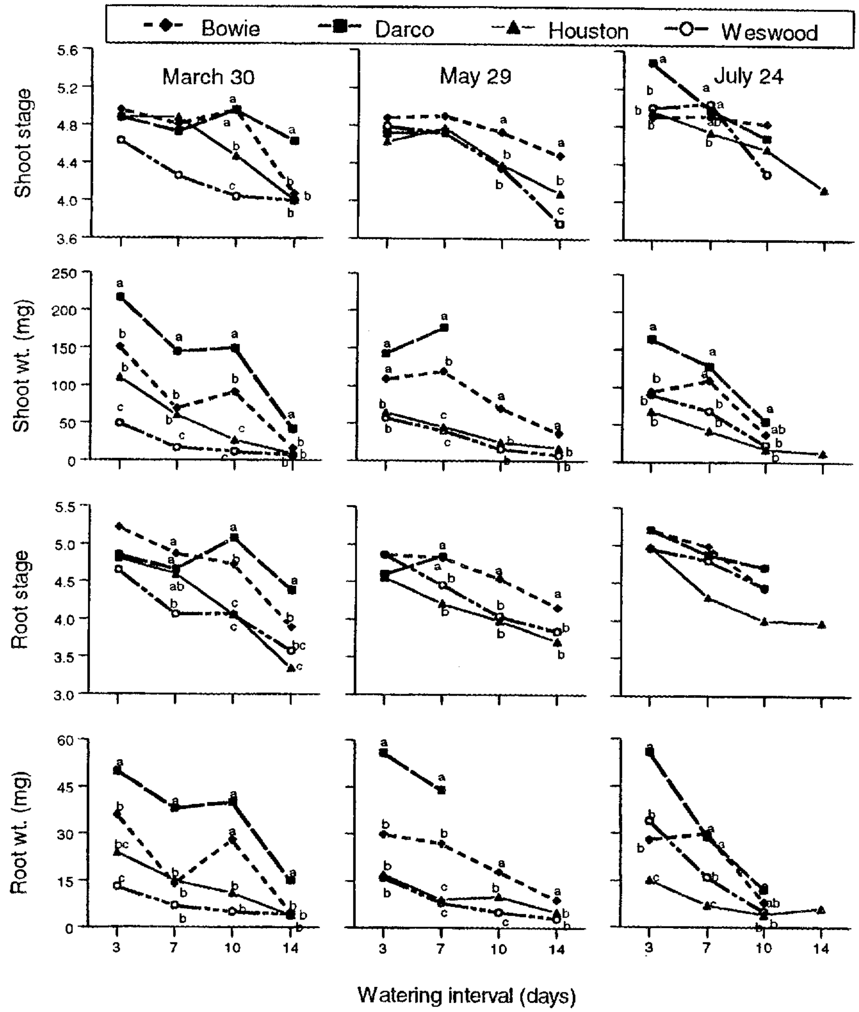

Fig. 5. Interaction of soil series and watering interval for shoot stage and weight and root stage and weight at 6 weeks for three dates.

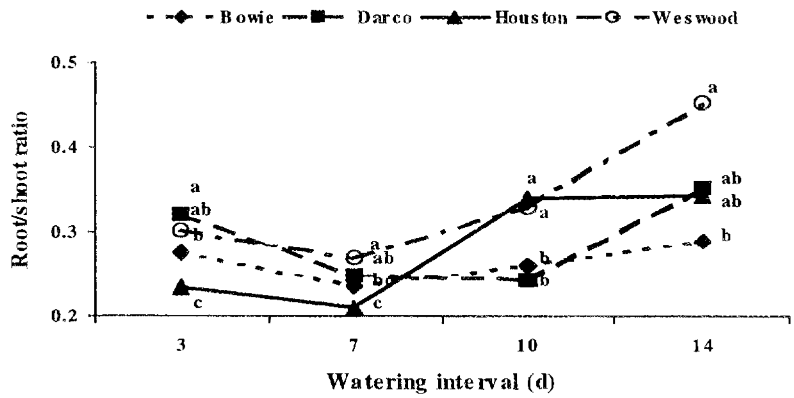

Fig. 6. Interaction of soil series and watering interval across dates for root/shoot ratio.

Influence of Temperature on Switchgrass Emergence

Background. As with most native warm-season perennial grasses, obtaining good stands is difficult because of small seed size, slow and erratic germination, and poor seedling vigor. Other factors inhibiting switchgrass establishment are seed dormancy and a seedling morphology causing permanent roots to arise from above the seed and near the soil surface. Therefore young seedlings are very vulnerable to drought. Temperature is a major environmental factor that influences seed germination, seedling emergence, and seedling vigor. A growth chamber study was conducted to determine the effect of temperature on switchgrass emergence to identify optimum planting times. Seed of Alamo and Lowdorm, southern ecotypes, and Blackwell, a northern ecotype, were planted in pots and placed in growth chambers set at day/night temperatures set at $68/50^0$, $77/59^0$, and $86/68^0$F. Seedling emergence was recorded daily for 28 days after planting.

Research Findings. Emergence increased as temperature increased but temperature did not affect total emergence by 28 days after planting (Fig. 7). By 8 days after planting, seedling emergence in the $86/68^0$F temperature treatment was near maximum emergence and was twice that of the $77/59^0$F treatment. None of the seedlings in the lowest temperature treatment had emerged by this time. The ranking of varieties for emergence rate and total emergence was Lowdorm > Alamo > Blackwell (Fig. 8). Lowdorm switchgrass was selected for reduced seed dormancy and it had a greater and more rapid seedling emergence than the other varieties. Maximum emergence was reached at 16 days after planting for the southern ecotypes Lowdorm and Alamo, and at about 24 DAP for the northern ecotype, Blackwell.

Day/night temperatures also influenced average shoot weight (Fig. 9), with the higher temperatures resulting in higher shoot weights. The average shoot weight (averaged over temperatures) was also affected by variety (Fig. 10), with Alamo showing a superior average shoot weight toward the end of the evaluation period.

Conclusions. In northeast Texas, temperatures from April through October should be adequate for total switchgrass seedling emergence. However emergence would be more rapid if planted in warmer temperatures from May through September if moisture were not limiting. Long term monthly rainfall for May and June exceeds 4 in. so that May should be the optimum switchgrass planting time in this area. The more rapid emergence should also make the switchgrass seedlings more competitive with weeds. Lowdorm switchgrass should be planted in the southeastern USA because of greater and more rapid emergence.

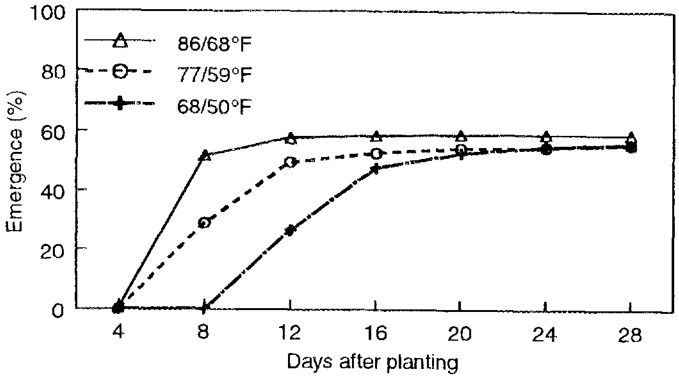

Fig. 7. Effect of day/night growth chamber temperatures on switchgrass emergence averaged across varieties.

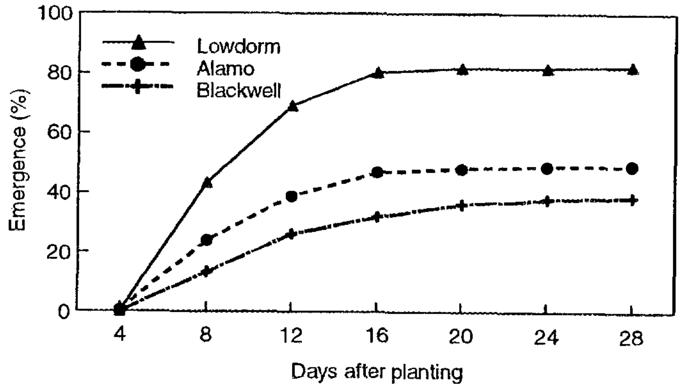

Fig. 8. Emergence of switchgrass varieties in growth chamber averaged across temperatures.

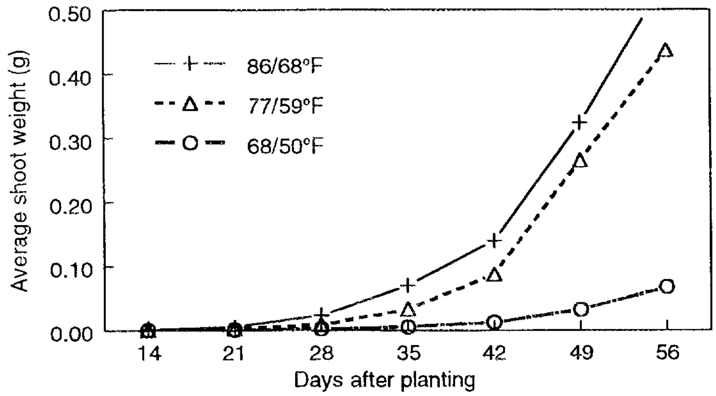

Fig. 9. Effect of day/night growth chamber temperatures on switchgrass shoot weight averaged across varieties.

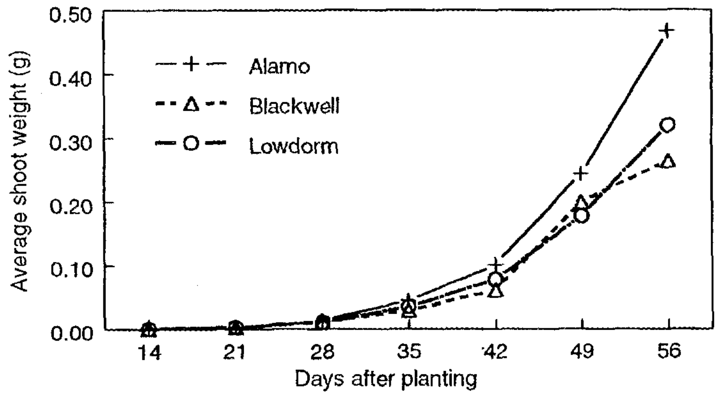

Fig. 10. Switchgrass shoot weight by varieties, averaged across temperatures in growth chamber.

Selecting for Low Seed Dormancy (Also see Section 5, Five-Year Project Report)

Methods and Materials. In the fall of 1992, we collected seed from established Alamo plants at Temple, TX. Within two weeks of collection, we put seed in the germinator (35°C, 25°C) and saved about 150 plants that germinated within two weeks. We transplanted these seedlings into the field at Stephenville TX, in April 1993. We harvested and bulked seed from these plants in October 1993, placed the seed in the germinator as described, and once again saved early germinators as described. Subsequent plants were placed in the field in Temple in 1994. In October 1998 we harvested seed from those plants, put it in the germinator, saved the early germinators and put them in the field at Temple in April of 1999. In the October of 1999, we collected seed from those plants, germinated the seed in the lab at room temperature, and saved early germinators. In March of 2000, 163 of these plants were placed in the field at Temple. In October and November, 2000, seed was harvested from 131 of the most desirable looking switchgrass plants, and placed in the germinator at 35°C 20°C. Germination counts (unreplicated) were totaled for seed from each plant for a period of 28 days. The 24 plants having highest germination were identified, dug from the field, subdivided, and subsequently planted (in four reps) at Temple and College Station TX in April of 2001. Both nurseries were kept well-watered during the summer of 2001. Seed was collected from each of the 24 plants at each location in October and November of 2001, and germination percentages were determined both at alternating (35C-20°C) and constant (30°C) temperatures. For each entry from both locations, germination was determined using four replications of 50 seed each, with reps blocked within a germinator. Analogous bulked control seedlots of unselected Alamo were also harvested both at Temple and College Station to serve as controls for the selected individuals at both locations. Because of variation in maturity dates, only 14 entries were tested in this experiment. These were the first 14 entries where adequate seed had been harvested at both locations for germination testing to be performed. Also, several off-type plants were dropped from the experiment.

Results. Data from the Fall 2001 germination experiment is presented in Table 5-3. In all cases (for both location and temperature), germination of seed of each of the 14 genotypes was significantly higher than that of the appropriate control. Germination of the Temple seed at alternating temperatures was especially high, with five of the 14 entries having greater than 90% germination. At alternating temperatures, with only one exception (Entry 44), germination of seed of all Temple clones was greater than that of seed of College Station clones. At constant temperature, germination of seed of all Temple clones was greater than that of seed of all College Station clones. The relationship between germination at constant vs. alternating temperatures differed between locations. The Pearson correlation coefficient for germination at the two temperature regimes for Temple seed was 0.2314 $P = 0.4468$), while for analogous College Station seed the correlation coefficient was 0.9129 ($P < 0.0001$). Although our experiments were not designed to specifically address this issue, the data we collected suggests a strong genotype X location X temperature interaction influencing germination.

Table 5-3. Germination behavior of seed of 14 clones of Alamo Switchgrass subjected to four cycles of recurrent selection for rapid germination. Temperatures employed were 35°C-20°C (Alternating), and 30°C (Constant). Germination experiments were performed in fall, 2001, within three weeks of seed harvest.

	Temple Seed				College Station Seed			
Entry	Alternating		Constant		Alternating		Constant	
	Percentage germination							
145	98.5	a	56.5	a	47.5	b	42.3	ebdfc
40	94.5	ba	73	a	41.5	b	37	edf
130	93	ba	73.3	a	38	b	41	ebdfc
60	90.5	bac	51.3	a	70.5	a	52.3	ebdac
87	90.5	bac	80.5	a	67.5	a	63.8	a
86	89.5	bc	60.3	a	72	a	54.3	bac
14	88	bc	54.5	a	78.5	a	57.3	ba
93	84	dc	51	a	47	b	37.8	edfc
30	82.5	dc	51.3	a	41.5	b	36.5	ef
114	79	ed	61.8	a	69.5	a	54	bdac
106	77.5	ed	65.5	a	64.5	a	51.5	ebdac
35	77	ed	50.5	a	35	b	28.8	f
44	73.5	e	65.3	a	74.5	a	67.3	a
Control	25	f	16.8	b	8	c	5.5	g

Screening for Seedling Mass

This research was initiated as part of a Ph.D. Dissertation project at College Station, TX. Hector Ramirez initiated this research in early 2000. He has completed the seedling screening on 180 plus single plant seed lots of seed we received from Taliaferro. There is no relationship between seed mass and seedling mass at 2 weeks after emergence (r^2 = 0.05). However, the first seedlings to emerge are larger (at 2 weeks after emergence) than the later seedlings that emerge. The heaviest seed-mass seedlings emerge more rapidly (64% by 5 days after planting for the heavy seed mass vs. 50% for the medium and low seed mass groups). The very heaviest seed mass families tend to have some of the heaviest seedlings (at 2 weeks after emergence), so we selected from this group (heavy seed and high seedlings mass) for our effort to enhance seedling establishment traits in switchgrass. The clones that produced these superior seedlings were dug from the field in Stillwater and brought back to College Station and maintained in the greenhouse during the summer of 2000. Out of those 180 genotypes we selected the top 10% (18 genotypes)and we cloned them 7 times to form the first crossing block (18 genotypes X 7 clones = 126 plants). The seed harvested in the fall of 2001 from this first polycross block is the "C1 base."

The graduate student has also screened seed from about 135 Cycle 4 Low-dorm clones maintained at Temple, TX (same seed lots that were evaluated for seed dormancy above). We also selected the top 10% of the plants and cloned them 4 times (15 genotypes X 4 clones = 60 plants). A few of these genotypes (4 or 5 genotypes) matched the selection made from Dr. Tischler (outstanding low dorm genotypes). We plan to harvest seed from this crossing block in the fall of 2002 and continue with the selection. Seed will be harvested from individual clones from the polycross nurseries.

We just completed growing the seedlings from the base population (C0 base) of switchgrass and the population we made selection for seedling mass from (C1 base). This will allow us to measure the improvement from the original population and the first cycle of selection C0 vs. C1. This was done in a growth chamber with 400 seedlings from every population and we included a check (buffelgrass....apomictic) to measure variability in the growth chamber. This check is needed for publication purposes. We have made selections from seedlings from this trial from C1 plants establish in the field in 2002, so we can set up the next crossing block.

TASK 6: EFFECT OF NITROGEN AND FALL HARVEST MANAGEMENT ON SWITCHGRASS YIELD AND PERSISTENCE

Objectives: The three objectives of this task are to: (1) determine the effect of five N rates and five dates of fall harvest (one harvest per season) on switchgrass biomass yield and stand persistence, (2) determine the effect of N rates and time of fall harvest on switchgrass biomass composition (biofuel quality), and (3) determine the effect of N on the developmental growth rate of switchgrass. This research will be conducted at three locations varying in rainfall and latitude (Dallas and Yoakum, TX and Hope, AR).

See five-year report for the overall summary of both the 2001 harvest data at Hope and Yoakum and the previous year's sample analysis at all three locations.

TASK 7: CUTTING HEIGHT AND FREQUENCY (Not funded)

TASK 8: SPACIAL VARIABILITY OF SWITCHGRASS BIOMASS PRODUCTION (Terminated)

TASK 9: ALTERNATE SPECIES (NEW in 2000)

Objectives: Since Switchgrass stands cannot be maintained at the southern locations in Texas, we will evaluate alternative species for their potential as a biomass crop. The two plants that we have agreed to evaluate are Bundleflower, *Desmanthus bicornutus* and native shrubby legume that is native to Mexico and Southern Texas, and Giant Reed, *Arundo donax*, a C-3 perennial that is found along the roadsides all over the eastern half of Texas.

<u>LEGUMES:</u> We planted 3 of the 4 native shrubby legumes that we have under evaluation in South Texas for forage at two locations (Beeville and Yoakum). These lines (BEDES-06, BEDES-37 and BEDES-57) are native to Mexico and the Southern USA. We originally selected these lines for their have excellent seedling vigor and drought tolerance, and they are well adapted to the calcareous soils of the region. We have determined from previous evaluations that they are well adapted to South Texas, but have not determined their yield potential for biomass. These legume are currently under evaluation for use as a wildlife food and cover plant. Preliminary data on its use as a wildlife plant are outstanding. For wildlife utilization, we have found that relatively low plant populations

are adequate. These legumes should require no N-fertilizer. We have not determined the P_2O_5 requirement, so we will also evaluate P_2O_5-fertilizer rates. We established the same experiment at two locations using 3, 10 and 20 lb/ac of seed. The experiment was established in a factorial designs to evaluate plant density and P_2O_5-fertilizer responses in the same experiments.

On May 1, 2000, we seeded 4 replications of 3 genotypes, and seeded each at 3 seeding rates (3, 10 and 20 lb/A of scarified and inoculated seed) at TAES-Beeville. The plan also called for a response to P-fertilizer rates, but those were not applied in 2000. These plots were irrigated as needed in 2000, as we received limited rain in the summer of 2000. We applied Pursuit and Fusilade to control the weeds. The plots were harvested on Dec. 8, 2000. December is too late to effectively harvest this plant, as leaf and seed shatter was in an advanced stage, but yields were in the 3000 to 5000 lb/A range, with the later maturing lines providing the highest yields. In 2001, 3 rates of P_2O_5 (0, 40 and 80 lb/A) were applied on May 8, 2001. No supplemental irrigation and no herbicides were used in 2001.

All plots were harvested for biomass yield on Oct. 29, 2001. There were no significant interactions and P-rate was not significant. There was a significant seeding rate effect as well as a difference among the 3 lines for yield. The mean dry matter yield of the seeding rates was as follows: 3 lb-rate = 6883 lb/A, and it was significantly better than the 10 and 20 lb-rates which were not different and were 6143 and 6109 lb/A, respectively. The 3 experimental lines are designated BEDES-06, BEDES-37, and BEDES-57, and the smaller the number the later the maturity (just coincidental). The observed mean dry matter yields were 7315, 6159 and 5515 lb/A for lines -06, -37, and -57, respectively and each was significantly different. These are respectable yields considering almost no rain from May through August. In addition, this is a native shrubby legume that was under development for both grazing and wildlife use, so the potential to add this legume to switchgrass based systems may prove useful as a N source as well as benefit wildlife. These lines of *Desmanthus* grow to about the same height at switchgrass and fix a fair amount of N from the air, thus *Desmanthus* might be a plant that could be grown in association with switchgrass in a no or low N-fertilizer input system to contribute to a lower cost biomass production system.

GIANT REED: Giant reed (*Arundo donax*) grows throughout the eastern half of Texas, and is also known to grow in California, and much of the Southeast. It appears to have tremendous potential as a biomass crop in Texas. This giant reed can be found along the highway right-a-ways in Texas down to the 20 to 25 inch rainfall areas and it extends further south and west than we have been able to grow switchgrass. It does not seem to spread except by intentional planting.

Giant Reed was established at TAES-Beeville on March 2 and 3 of 2000. Four blocks (each 85 by 22 feet) were planted using mature canes laid 3 or 4 wide overlapping in trenches about 3 to 5 inches deep. The trenches were 36 inches apart. The area was irrigated as needed throughout the 2000 growing season. On April 4, 2000 the entire area was sprayed with 1 quart per acre of 2,4-D. That application of 2,4-D did control the broadleaf weeds we had, but was also quite detrimental to the Reed, especially on rep 2. On May 18, 2000, 100 lb/A of N as urea was applied uniformly to the entire area. The growth from 2000 was not removed. On May 1, 2001, N fertilizer treatments were applied in 15-foot wide strips across each rep (Rep 2 was still had a fairly weak stand at the time we put on the N-fertilizer). Rates of N were 0, 40, 80, 120, and 160 lb N per acre as urea. We received very limited rainfall after fertilizing the plots until late August. Plots were harvested on 1-22-02 and 1-23-02, using a sickle bar cutter. A 6 foot 11 inch area was cut in the middle of each plot, the entire length of the plot (21 foot). Plots were cut to a 5 inch stubble. Samples of several canes from each plot were chopped in a hammermill to facilitate drying. Dry matter yields were determined and the data analyzed via SAS. There was no N-response ($p = 0.94$) and the mean yield over the 3 N-treatments was 9082 lb/A with Rep 2 left out, or 8298 lb/A with Rep 2 included (Rep 2 was severely damaged with the 2,4-D treatment in 2001, and had a lower stem density). The lack of N-response has been reported before for this crop (last year we reported a response to only the first 50 lb of N on an established stand near Halletsville, TX) , but it may also have something to do with that fact that we received limited rainfall for nearly 4 months after we applied the N fertilizer and Halletsville normally gets nearly 30% more rain than we get at Beeville. The 2001 yields are comparable to the 2000 yields from plots with no added N.

TASK 10: IRRIGATION RESPONSIVENESS OF ESTABLISHED ALAMO SWITCHGRASS (New in 2000)

The objective of this task will be to evaluate the potential response to targeted irrigation on land that is considered prime switchgrass growing land. We compared non-irrigated with 2 irrigations in mid-summer. The N-rate was intended to be high enough that N was not limiting.

This task was established at College Station in the spring and summer of 2000. The first attempt was by direct seeding, which was a failure. Therefore, several thousand seedlings were started in the greenhouse and transplanted into an adjacent area in June of 2000. The planting configuration was 36 inch rows with plants space 1 foot apart in the row. The entire area was fertilized with 150 lb/A of N on Apr. 17, 2001. We had a wet spring at College Station (see rainfall summary tables at the end of this section), so irrigation was not applied until July 23 and then again on August 10. The rainfall record show that College Station received over 8 inches of rain in August, but it came in the last 2 or 3 days of the month. On Sept. 21, 2001, 6 rows 200 feet long were harvested in the irrigated block and 6 rows 200 feet long were harvested from the non-irrigated block. The dry matter yield from the non-irrigated block was 17,657 Kg/Ha, while the irrigated block produced 23,288 Kg/Ha. Due to layout of the irrigation system, replication was not possible, so there is no way to statistically analyze the data. However, this does support other irrigation observations we have made, and does support the data gleaned from the Variety Trials conducted over 18 location-years, that water (rainfall) in the May through July period accounts for most of the variability in annual yields.

TASK 11: CROP RESIDUES (New in 2000)

Objective: The objective is to document stubble yields from corn and sorghum crops grown at four locations in Texas and compare them to the grain yields on the same plots.

Alternate biofuel sources to supply a biofuel conversion plant would include the biomass that is produced in corn and sorghum production in years when there is a (corn or sorghum) crop failure. It is anticipated that in drought years, corn, and to a lesser extent sorghum, that is traditionally planted for grain will have an opportunity to be used for fuel, as partial to complete crop failures are common in much of Texas. These corn/sorghum crop failures will also likely coincide with periods when dedicated biofuel production will be depressed. We collected stubble yield data on existing non-irrigated plantings to document available biomass in corn and sorghum variety trials. This data was collected from ongoing research supported in part by regional corn and sorghum variety trials. Table 11-1 provides the grain and stubble yields for 2 locations of corn and sorghum. The 2001 data suggests that corn residue will likely not provide sufficient yield in Texas to warrant the harvest. However, Grain Sorghum residue at least at the Granger location appears to be more promising in terms of yield per acre to justify harvest.

Table 11-1. Corn and Grain Sorghum residue and grain yields at Granger and Prosper, TX in 2001.

Location	Crop	Variety	Residue Yield	Grain Yield
Granger	Corn	DK 689	2960 lb/A	115.7 bu/A
Granger	Corn	Pioneer 3223	2030 lb/A	130.7 bu/A
Prosper	Corn	DK 697	1270 lb/A	51.9 bu/A
Prosper	Corn	31 B13	1065 lb/A	61.4 bu/A
Granger	G. Sorghum	DK 54	6924 lb/A	8288 lbs/A
Prosper	G. Sorghum	DK 54	2474 lb/ A	4530 lb/A
Prosper	G. Sorghum	ATx378xRTx430	2385 lb/A	3442 lb/A
Granger	G. Sorghum	ATx378xRTx430	6009 lb/A	6586 lb/A

The above data were provided by Dennis Pietsch and the Texas A&M University crop testing program. All sites are dryland. The stover (residue) represents the harvest of 2 replications in September of 2001. Granger is located due west of College Station and due south of Temple. Prosper is located north of Dallas.

Seed Production of Low-crown Switchgrass

We flood irrigated our part of our seed production are this last summer. This allowed us to produce some good quality seed of our low crown line at Beeville. The seed has been cleaned and is in cold storage.

PLAN OF WORK FOR 2002

Most tasks still have data to be analyzed and manuscripts to be written. Most all the laboratory nutrient analysis (fiber and minerals) has be completed, but the amount of data we have will take some time to completely analyze and interpret all the findings, so much of this final year's effort will directed toward analysis and interpretation of the information we have collected along with the publication of the data. We do have some tasks that still need work, and we have two graduate students that still need to complete their research and write their theses/dissertations. We also have some tasks that still need one more repeat to obtain enough data to draw final conclusions and publish the results.

Task 2: Soil Quality. There are still soil samples from the fertility studies at Yoakum and Hpoe that need complete analysis, and we took some samples to 1 meter deep in College Station in April of 2002 that need soil Carbon analysis.

Task 5: Switchgrass Establishment. Background: Seedling establishment problems have plagued this project (and several other projects in the south) since we started working on switchgrass as a biomass plant. Frequent stand failures or poor stands have prevented or delayed several planned studies associated with this project. We feel we can solve this problem if we take a multi-pronged approach. (1) To improve the chances of a seedling competing with the weeds, we need to identify one or more herbicides that will not be phytotoxic to switchgrass and also do a reasonable job of controlling the major weeds in the field. We think our best chances here are to protect the seed from the phytoxicity of the herbicide with some form of a safener. We have completed one experiment with activated carbon as a safener, and it seems to work. This experiment needs to be repeated and field tested. (3) And perhaps the most promising approach will be to improve the seedling characteristic through selection (breeding) for traits that will make the seedling more competitive in the field. To determine which trait(s) might best be incorporated into a breeding program, we will evaluate the potential impact of several seedling traits in both controlled environment and field conditions.

Herbicide Evaluation with a Safener. Herbicide evaluation will be done at Beeville and or Yoakum. To increase our chances of identifying herbicides with low levels of phytotoxicity, we will only conduct research in the greenhouse and use sterilized soil. These controlled environment studies will allow us to isolate weed pressure issues from phytotoxicity issues, and eliminate other factors such as soil nematodes or other soil borne issues. We will repeat the study we completed in 2001 with activated carbon sprayed in a band right over the row to protect the switchgrass seedling by deactivating the herbicide. This technology has been used in the grass seed industry for more than 30 years, but has never been reported on switchgrass. This will make our data from last year publishable.

Evaluation of Traits that Control Improved Seedling Vigor (NEW in 2000). Part of this modified TASK will be to select and evaluate for multiple seedling traits in separate tests. We plan to utilize procedures that have proven to work for other *Panicum* species. Seedling vigor depends on many factors, but three important ones are: (1) amount of seed reserves, (2) efficiency of capture of seed reserves, and (3) efficiency of utilization of seed reserves. This effort is a slow process as once the traits are identified in the seeds of a clone, we have to go back to the nursery where the seeds were grown and dig the plant out, divide it into several ramets, and re-establish it in a polycross nursery where it will be allowed to cross with other clones with superior traits, and produce seed. Since switchgrass only flowers once per year, it can take one to two years before the next set of seedling traits can be evaluated. All these evaluations will be done in controlled environment conditions as part of a Ph.D. Dissertation project under the direction of Drs. Ocumpaugh, Rooney, Burson and Tischler. Dr. Charlie Tischler, a plant physiologist with the USDA-ARS unit at Temple, has developed and tested these protocols for selection for improved seedling traits on grasses. **(This will require a full two or three years to make good progress; it will take more than four years to optimize progress.)**

At Temple, Charlie Tischler will continue to work on the Low-Dormancy selection and evaluation work (including back crossing it to low crown material) to bring that project to a close.

Task 6: N-rate by Fall Harvest Management. We plan to make a spring harvest on the plots at Hope and Yoakum to determine carry-over effects from the multi-years of differential cutting and N-fertilizer applications. It will be a single harvest of all plots on one date. (This will match-up with a similar harvest that was taken in the spring of 2001 on the Dallas plots). This will be the final measurements to be taken on these plots. This data will need to be analyzed and published.

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