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To the Graduate Council:

I am submitting herewith a dissertation written by William Eugene Bryan entitled "Yield Probability Evaluations for Summer Annual Forages on Some Tennessee Soils." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Agricultural Plant and Soil Science.

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YIELD PROBABILITY EVALUATIONS FOR SUMMER ANNUAL FORAGES ON SOME TENNESSEE SOILS

A Dissertation

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

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by

William Eugene Bryan

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ABSTRACT

Experiments were conducted to determine the effects of soil type, moisture regime, and date of planting on the yield and associated characteristics of corn silage, corn grown for grain, tall and medium height forage sorghums, and pearlmillet. Early and late plantings of each crop grew on 12 soils (at six locations, 1965-1969) encompassing wide ranges of physical and chemical properties. Irrigation treatments were included in 1969 on five soils at three locations. Corn and sorghum tissue samples were collected at the end of the 1969 growing season and analyzed for total uptake of N, P, K, Ca and Mg. Yield of each forage crop was measured for 82 location-treatment-years. Variations in temperatures and precipitation patterns were evaluated for each experiment. A total of 51 independent variables consisting of 35 "soil-variables" and 16 climatological terms were included in the preliminary multiple regression analyses for each crop. Two models (Model I and Model II) were employed and evaluated as to their relative usefulness in estimating variation in yield for each forage crop. Model I differed from Model II in that certain "soil-variables" appearing in Model I were assessed and described in Model II. Soil data included in Model I were percent sand and silt, and pH of horizon 1, 2, 3; whereas, Model II employed bulk density, base saturation, and available P and exchangeable K of each horizon. Thus, the two models have different degrees of application with Model I being a "simple" model requiring fewer determinations to facilitate its use. Model II on the other hand requires more extensive data. The same climatic variables and their interactions were included in both models.

In general, the soil with the most desirable moisture characteristics in the "pair" at each of the six locations resulted in higher crop production. Although yield fluctuations at each location were noted among years, the yield at any one location generally remained higher for that soil having a higher moisture supplying capacity.

Total dry matter and grain production were usually higher from the early plantings than from those planted four to five weeks later; conversely, the delay in planting usually resulted in more dry matter produced after August 1 by greenchopped crops (Sudax SX-11 and Gahi-1).

Even though rainfall during the 1969 growing season was considered to be favorable for high yields, irrigation increased dry matter yields of corn, grain sorghum, and forage sorghum. On the other hand, supplemental irrigation of Sudax SX-11 and Gahi-1 increased neither total yield nor yield after August 1. Therefore, the two greenchopped crops were affected less by moisture stress than were the silage crops.

Total (seasonal) uptake of N, P, K, Ca and Mg in above-ground plant parts of corn or grain sorghum was generally no different between soils at each location when not irrigated. Where differences in observed seasonal uptake of certain elements existed, usually the irrigated and early-planted crop resulted in higher uptake than the crop planted four to five weeks later.

In the multiple regression analyses, the coefficient of total determination (R^2) for the five forage crops ranged from 0.473 for Gahi-1 to 0.741 for corn silage, using Model I. When Model II was employed, the R^2 values ranged from 0.500 for Gahi-1 to 0.730 for corn silage.

Approximately three-fourths of the variation in corn silage yields in these experiments was accounted for by the 16 variables kept. The low R^2 for Gahi-1 indicates that Gahi-1 yields are influenced less by variations in meteorological and soil conditions than the four other crops studied.

In this study, Model I was preferable to Model II because of its general consistency in predicting the variation in crop yields. Model I also employed fewer variables and these were variables which can be measured with greater ease (require less scientific expertise) than those included in Model II.

From the multiple regression analyses, it was concluded that moisture supply generally accounts for much of the variability in each crop-yield. The analyses indicated the negative relationship between exchangeable Mg and yield in the equations. The yield-magnesium relationship may be a secondary effect to increased clay content with increasing depths and the additional effects produced by higher clay content and lower pH value may account for the reduced plant growth.

Within the range of data studied, yield was usually independent of the linear effects of the time-temperature index; however, the interactions between degree-days accumulated during the growing season and available waterholding capacity, and accumulated degree-days and precipitation, were generally found to be effective predictors of yield.

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CHAPTER I

INTRODUCTION

A great deal of attention has been given to the physical and chemical properties of many Tennessee soils. Previous studies have shown that summer annual forages behave differently when grown on different soil types. In addition to the physical and chemical characteristics of a given soil, many other environmental conditions, such as precipitation, temperature, light, wind, etc., influence the yield and quality of crop plants.

Although the agriculturalist is not yet able to change the weather, he is capable of adjusting his cropping system in such a way that crop efficiency may be increased. To do this, the producer may benefit in one or more of three principal ways:

1. By relating climatological measurements to specific soil-crop situations and predicting the microenvironmental effects.
2. By selecting or altering the production site to fit a given crop.
3. By adopting recommended production practices such as irrigating, adjusting the plant density, and varying planting dates.

As a result of having obtained a better understanding of the complex interaction between crop growth and development and the ecological factors encountered, a farmer may find it possible to reduce much of the variability in year-to-year yields of summer annual forages grown in Tennessee.

The objectives of this study were threefold:

1. To determine the interrelationship of soil types and environment on yield and associated characteristics of corn (*Zea mays* L.), grain sorghum (*Sorghum bicolor* (L.) Moench), forage sorghum (*S. bicolor* (L.) Moench), a sorghum-sudan hybrid (*S. bicolor* (L.) Moench), and pearlmillet (*Pennisetum typhoides* (Burm.) Stapf. and C. E. Hubb).
2. To relate soil characteristics to uptake of N, P, K, Ca, and Mg by corn and grain sorghum from 12 soil types at two planting dates using irrigation treatments.
3. To develop regression equations that describe summer annual forage production on some Tennessee soils.

The investigation described in the present report was intended to complete the agronomic phase of a three-phase summer annual adaptation study. Manning (39) reported on variation in P, K, Ca and Mg content in plants at different stages of corn and grain sorghum growth when grown under a wide range of environmental conditions. He considered relationships between concentrations of the four elements and soil types, planting dates, and moisture regimes.

In another phase of this study, Oonmuang (45) investigated and compared selected chemical characteristics within and among the 12 soil types. Thus, the two soil types at each of the six locations were common to all three phases of the summer annual adaptation study.

CHAPTER II

REVIEW OF LITERATURE

In order to achieve the crop production potential of a given soil-crop situation it is necessary to have a knowledge of soil and plant growth relationships to be able to characterize an optimum environment for a particular plant. Limitations of inadequate plant nutrients have been recognized and studied for decades. More recently investigators concerned with optimum plant yields have recognized the importance of the interrelationships among plant population, soil moisture, soil fertility, temperature, and many other variables which may influence yields.

I. FACTORS AFFECTING WATER UTILIZATION

Numerous plant, soil and climatic factors affect the supply of water available to plants. Key plant factors involved include the rooting habits (depth, degree of ramification, and activity), the stage of plant development as affected by level of nutrients, stage of growth, and degree of turgor, and plant resistance to drought. Relevant soil factors include moisture tension relations, soil depth, soil stratification, including the effect of fragipans and textural layering, soil temperature and temperature gradients. Important climatic factors are evaporation and transpiration losses as influenced by air temperature factors and humidity, fog, wind and sunlight (29).

Transpiration of water by plants has been studied for the past two centuries, but until recently very little was known about relationships between water and plant growth, except that plants require water to survive. Briggs and Shantz (11) made the first actual measurements of the water requirements of crop plants during the early part of this century. They recognized that water loss was actually affected by two processes--that from the soil, called evaporation, and that from the plant, called transpiration. Later the two processes were combined and the concept of "consumptive use" or "evapotranspiration" was developed. Consumptive use or evapotranspiration (ET) is the unit amount of water used on a given soil area in transpiration, building of plant tissue, and evaporation from adjacent soil, snow, or intercepted precipitation in any specified time (9).

Penman (48) defined potential evapotranspiration (PE) as the amount of water loss per unit time by a short green crop of uniform height, completely shading the ground, and well supplied with water and plant nutrients. Actual ET may or may not approach PE, depending upon certain plant, soil, and climatological factors.

Climatic factors believed to have the greatest effect on moisture use are temperature, precipitation, humidity, wind movement and length of growing season (19,31,47). These factors act independently of both soils and plants, which are considered to have modifying effects upon the climatic factors (8,19). Phallas et al. (50) stated that purely physical parameters accounted for approximately 90 percent of the variability of transpiration rates of soybeans and the remainder was probably due to biological factors. Similarly, Hodges (28) noted in Kansas that the effect of rainfall and temperature on corn yield was quite variable, and that July droughts affected corn yields adversely.

With adequate moisture present, consumptive water use is probably affected more by temperature than by any other factor. Plant growth ceases when the temperature drops below a certain minimum value or exceeds a certain maximum value; but in the intermediate range, an increase in temperature is accompanied by increased growth and ET rates (8). Ragland et al. (52) found that temperature exercised a greater control on the rate of corn leaf growth than did solar radiation or relative humidity. Although Wilcox (74) showed that solar radiation gave the highest correlation with ET of alfalfa, ladino clover and bromegrass on an hourly basis, temperature gave the highest correlation with ET on a daily or weekly basis. Smith et al. (61) stated, "The soil does not really come to life until its temperature exceeds 42° F., and the pace quickens rapidly as the temperature rises above 45° F."

Heat unit summation is widely used for many crops in indexing and predicting maturity through the development of a single value expressed in degree-days. Newman et al. (44) stated that the base temperature for corn is generally considered to be 10° C. Vittum et al. (70) reported that the growing-degree-days method is very effective in comparing or contrasting the thermal climate for different locations and/or years.

Evaporation and transpiration are accelerated by low relative humidity and reduced by periods of high humidity. Likewise, air currents set up conditions which allow for a more rapid transfer of water vapor than do calm conditions (26). Beuerlein et al. (7) found that dry matter yields of a sudangrass-sorghum hybrid, cultivar 'DeKalb Sudax SX-11' were highly correlated with precipitation, wind, and total radiation.

Day length and length of growing season have cumulative effects. Their effect upon rates of consumptive water use is related to the time interval during which transpiration takes place rather than with intensity (2).

Total precipitation and its distribution are important controlling factors on water use by plants. Precipitation above the storage capacity of a soil is lost through runoff or deep percolation. Alessi and Power (1) reported that corn forage and grain yields were linearly related to soil profile moisture at planting, plus seasonal precipitation. More than 15 cm of total available water had to be present before any grain production could be expected. For each additional cm of available water, about 0.65 t/ha of silage and 0.21 kg/ha of grain could be expected. Rust and Odell (57) concluded that more yield variation was associated with weather factors than with N, P and K added, cropping systems followed, and lime applications.

Power and Evans (51) stated that soil texture, structure and pore space affect evaporation indirectly, and thus influence water requirements. Peters and Russell (49) reported that evaporation from the soil surface accounts for 50 to 70 percent of the total water loss from a corn crop.

II. CROP GROWTH AND NUTRIENT UPTAKE

Plant growth is primarily a result of two major processes: cell division and cell enlargement. Wadleigh (72) reported that soil moisture deficits affected plant growth mainly by inhibiting cell enlargement rather than cell division. As the moisture stress is increased, the turgor pressure within the plant is reduced. Turgor pressure is the force that brings about cell enlargement; thus, moisture stress may reduce plant growth through a reduction in turgidity of plant tissue.

Early research into soil-plant-moisture relationships resulted in the concept that plants performed equally well in soils having widely different moisture contents; however, differences of opinion are held as to the relative availability of soil moisture to crops over the range from field capacity to the permanent wilting percentage (37).

Wadleigh (72) stated that there is evidence that soil water between field capacity and the permanent wilting point is equally available to crop plants. Perhaps a more prevalent view was given by Taylor and Haddock (65) who reported a decrease in the transpiration rate of a plant with a decrease in the soil moisture content.

Although it may be assumed that soil water held between 0.3 to 15.0 bars tension is available to plants, the growth of most crops is usually found to be affected when the moisture tension exceeds four bars (54).

The lack of sufficient moisture for optimum plant growth has received considerable attention. Van Bavel (69) defined agricultural drought as a condition in which there is insufficient soil moisture available to a crop, and a "drought-day" as a period of one day during the time when this condition exists.

A drought-day, used as a measure of drought intensity, was considered to occur when the available moisture in the soil for the soil-plant relationship in question was exhausted, as estimated from rainfall and evapotranspiration data by a moisture balance method. This measure has considerably more meaning as a measure of drought intensity than rainfall data because of inclusion of relevant climatic, soil and plant factors that contribute to drought (52).

Thornthwaite (67) working with lysimeters and watersheds in central and eastern United States, developed a formula for estimating potential ET. The formula derived was:

$$E = 1.6\ (10T/I)^{a}$$

where E = the unadjusted (30 days, each a 12 hour day) potential evapotranspiration in centimeters, T = the monthly mean temperature in degrees C, a = a constant that varies with location, and I = the annual heat index. The annual heat index I is the sum of 12 monthly heat indices, where $i = (T/5)^{1.514}$. The constant a is equal to $0.49239 + 0.01792I + 0.0000771I^2 - 0.000000675I^3$. The unadjusted PE may be corrected by using the actual daylength for each month, to give the adjusted PE. Thus, Thornthwaite expressed the potential evapotranspiration as an exponential function of the mean monthly air temperature, and he applied a daylength adjustment to correct for season and latitude. He justified the omission of other meteorological elements by stressing the fact that they vary together with air temperature.

Experiments in successive years usually result in large variations due to year-to-year variation of such factors as precipitation, temperature, light intensity, etc. Even within the same year, drought variability may be related to geographical location, soil properties and existing weather conditions; therefore, the amount and distribution of rainfall and the consumptive use of water by plants are of principal significance.

Parks and Knetsch (46), working with Starr millet, related yield to drought intensity during three stages of growth and accounted for 94.8 percent of the variation in yield by fluctuation in soil moisture. Growing season drought-days were found to be most prevalent in June, July and August-September in the Tennessee Valley.

Letey and Peters (37) found that although corn yields usually were inversely correlated with soil water stress, yields depended on both the precipitation pattern and temperature. Therefore, it seems that irrigation effects may vary greatly between cool summers with low ET rates and hot summers with high rates.

Parks and Lillard (47) estimated that about 217 to 310 kg of corn could be produced per ha-cm of available water if all other production factors are at an optimum level. They found that maximum moisture use was reached just prior to tasseling and remained relatively high through kernel formation.

Taylor et al. (64) conducted experiments on soils with high bulk densities and pans to determine their effects on yields of grain sorghum. In 1952-1956, a period of low precipitation, they found severely distorted sorghum rooting patterns with average yields of 103 kg/ha for above-ground growth. During 1958-1963, average precipitation and yields were greater than normal and sorghum rooting patterns were not distorted. The investigators concluded that soil pans have a marked effect on the yield of grain sorghum.

Plant species and cultivars may respond quite differently to moisture and fertility levels. Smith and Clark (60) compared pearlmillet and sudangrass on a mineral-deficient and low pH soil at four rates of P and K and at three rates of Ca and Mg fertilization. Large differences were noted in the growth of the two crops: pearlmillet was less sensitive to soil fertility while sudangrass failed to survive where pH and fertility were low.

Wittsell and Hobbs (75) showed that sorghum grain and stover yields and sudangrass forage yields were depressed by soil compaction. Grain sorghum yields were reduced from 7.3 to 6.0 t/ha by compaction and sudangrass yields were reduced from 12.0 to 6.3 t/ha by heavy soil compaction.

Russell and Danielson (56) found that mature corn used water to a depth of 1.5 m or more on a deep permeable, well drained soil. Nakayama and Van Bavel (43) injected radiophosphorus at soil depths of 15.2, 30.5, 45.7, 61.0, 91.4, and 121.9 cm and at lateral distances of 12.7, 25.4, 38.1, and 50.8 cm from the row to determine the relative root activity of sorghum. They attributed 90 percent of the root activity to a zone 91.4 cm deep extending 38.1 cm from the row. Total root extension was 76.2 cm on the sides and at least 152.4 cm deep.

Bennett et al. (4) found that sudangrass, pearlmillet, and sorghum extracted moisture mainly from the top 61 cm of soil from emergence to the time they reached heights of 30.5 cm. Both depth of extraction and amount of water extracted increased with increased growth. An average for 1960 and 1961 showed that moisture had been extracted to a depth of 121.9 cm by the time of harvest. It is recognized that moisture stress affects plants to varying degrees, depending upon the state of growth. Moisture stress was defined by Shaw and Laig (58) as being the result of an imbalance between the water supply furnished by the soil and the amount needed by the plant, as determined by atmospheric conditions, assuming a complete soil cover by the crop.

According to Robins and Domingo (54) moisture depletion of soil to the wilting percentage for periods of one to two days during tasseling or pollination resulted in a 22 percent reduction of corn grain yield, while periods of six to eight days reduced grain yields by as much as 50 percent.

McKinney (41) considered the growing period of corn to be 126 days, which he divided into nine 14-day periods. He found that water use was low during the first period as plants were emerging from the soil and increased gradually during the next two periods. During tasseling, silking, and grain formation, water use reached its peak rate. The last two periods resulted in a gradual decrease in water use. He further observed that irrigated plots averaged using 5.1 and 9.5 cm per year more water for Jackson and Knoxville, respectively, than did the nonirrigated plots during the five year study.

Miller and Duley (42) divided the corn growing period into three 30-day periods and found that the moisture supply during the second period influenced total dry matter production more than it did at any other time.

In an Iowa corn study, Shaw et al. (59) found the highest correlation between water use and corn yield during the period June 15 to

August 1. Average daily water use during 1954, 1955, and 1956 during the period mid April to mid June was 2.5, 2.3, and 2.0 mm; during mid June to mid August 4.6, 4.6, and 3.8 mm; and during mid August to mid October 2.3, 1.8, and 2.0 mm respectively.

Bennett et al. (4) reported that water use was higher during the first than for the second planting of sudangrass, pearlmillet and sorghum grown at three moisture regimes. Yields increased as the moisture level increased among all three forages.

Fribourg (17) in Tennessee reported that the annuals sudangrass and pearlmillet produce a large quantity of forage during July, August and September, a period during which unfavorable climatic conditions bring about a decrease in production of perennial forages. Evaluation tests showed that regrowth after clipping depended on management practices. He reported 'Gahi-1' pearlmillet yields of about 6.7 t/ha of dry matter from three to four regrowths when allowed to reach a height of 76.2 cm and cut back to 15.2 cm stubble.

Benoit et al. (6) conducted experiments in Kentucky on a Maury silt loam to study the effects of three planting dates and two moisture levels within each date on the yield of corn. They found that yields decreased with delayed plantings, regardless of irrigation treatments. Irrigation gave an average increase of 55 percent in 1962 and only 9.6 percent in 1963. They concluded that the magnitude of these increases was a result of the moisture and temperature regimes under which the plants grew.

Cook and Parmer (15) found little differences in yield among sorghum planting dates during a period of deficient rainfall in Texas, but during the following season when rainfall was adequate, yields were reduced with each later date of planting from March 13 to June 14.

Broyles and Fribourg (12) studied the influence of N fertilization in relation to cutting management of sudangrass and millet. Fertilization levels of N (0, 67.3, and 134.6 kg/ha) and clipping intensity treatments were related to dry matter production. Yields obtained were highest when cutting at 76.2 cm to a height of 25.4 or 15.2 cm, and least by cutting at 50.8 cm to a 15.2 cm stubble. Higher levels of N fertilization increased the yield of dry matter.

Many plant nutrients are required for forage production and prominent among these nutrients is N. Long (38) stated that corn yielding 7800 kg/ha (grain) would remove 1790 kg of N, 62 kg of P, and 123 kg of K from the soil. Similarly, Jordan (30) found that corn required high N applications.

Smith (62) further stated that little response by corn was obtained from the application of N in the absence of adequate quantities of P, K, Ca and Mg.

Beeson (5) reported that soil differences influence the chemical composition of plants, but differences due to soil and those due to other factors (such as rainfall, temperature, etc.) were often difficult to separate. Ketcheson (32) found that increasing the temperature from 13° C to 20° C resulted in greater P uptake and dry matter production in corn.

The phenomenon of plant nutrition is frequently evaluated by analyses of plant tissue, assuming that plant nutrition rests upon the fact that under normal conditions the nutrient concentration within the plant reflects the capacity of the plant to grow and acquire nutrients from the soil. From a practical standpoint, this means that the inorganic nutrition of plants is essentially concerned with the uptake of nutrient ions from the soil into the plant system. Fried and Broeshart (18) stated, "As long as the plant is alive and its roots are in the soil, the soil-plant system with regard to inorganic nutrition is an open system in which nutrient ions are continuously removed from the system at one end (the solid phase) and accumulated at the other end (the plant), as shown in Eq. (1.1) where M is a nutrient ion. M (solids) $\rightleftarrows$ M (solution) $\rightleftarrows$ M (plant root) $\rightleftarrows$ M (plant top) (1.1)."

The absorption of minerals by intact plants includes several steps or processes, the principal ones being (a) the movement of ions from the soil and soil solution to root surfaces, (b) ion accumulation in root cells, (c) the movement of ions from the root into the xylem, and (d) translocation of ions from the roots to the shoots (35). Cells accumulate ions to a concentration higher than that in their environment. One theory of accumulation proposes that anion accumulation is by active transport linked directly to metabolism and that cations move passively along the gradient of anions. A more widely held theory assumes that ions form temporary combinations with special organic molecules called carriers, and that the resulting complex can move through cell membranes which are impermeable to ions alone. The ions then separate from the carriers at the membrane surface and move into the vacuoles, while the carrier molecules become available to move more ions. Metabolic energy is required for the synthesis of carrier molecules and for maintaining membrane structure.

The kinds and amounts of ions accumulated by root cells varies with the plant species, with the metabolic activity of roots, the kinds and concentrations of ions in the "soil," soil temperature, and aeration. Mobile ions such as NO_3^- and K^+ move toward roots in the soil solution, but immobile ions such as PO_4^{---} are available only from the soil in the immediate vicinity of roots. Different theories have been proposed to explain how ions move radially from the root surface into the stele and enter the dead xylem. The classical explanation is that ions are accumulated by the cells at the root surface and move inward through the symplast to the stele by diffusion and cytoplasmic streaming. Ions which reach the xylem sap of the roots are usually carried to the shoots in the transpiration stream; however, much is removed from the xylem sap by adjacent living cells, and the salt concentration of the xylem decreases from roots to shoots. Explanation of the movement of ions to the shoots is complicated by the fact that some inorganic ions are converted to organic ions in the plants. Furthermore, many mobile ions remain in a constant state of flux, being moved from old to young leaves, and some ions carried to the shoot in the transpiration stream are moved downward again in the phloem. Continuous changes in the movement of ions in plants result in various theories as to plant-cell and ion behavior.

Relatively little work has been done with nutrient uptake and accumulation by grain sorghum. Kramer (34) reported that the P, K, Ca and Mg contents of grain sorghum and corn were similar when grown on the same soils; however, Manning (39), working with the same 12 soils as in this study, concluded that corn leaf tissue contains higher concentrations of K, Ca and Mg than leaf tissue of grain sorghum of the same chronological age. Regarding the importance of K, Manning added, "In most cases, the difference between K contents of two soils played a more important role in determining the comparative levels of each of the elements K, Ca and Mg within plants grown on the soils than differences between the Ca or Mg contents of the soils."

III. APPROACHES TO EVALUATING CROP-WEATHER RELATIONSHIPS

There is much interest in developing better methods of interpreting experimental results. The earliest investigations of crop-weather relationships centered around simple correlation studies where the yield was correlated with one factor. Many such studies resulted in low correlations because there are several factors that determine yield (71). More recently, comprehensive analyses have related crop yields to several factors and applied multiple regression methods (27). Fisher (16) formulated a method of dividing the growing season into as many periods as possible without excessive complications in the correlation equation. This method provided for a time identification of the weather variable under study.

According to Hendricks and Scholl (27), who studied corn yield estimates for Indiana, Iowa, and Ohio, "Corn yields apparently cannot be predicted much more accurately from weekly weather data than from monthly weather data; however, an analysis based on weekly weather data enables one to determine the seasonal variation of the effects of weather factors more accurately."

Walker and Pesek (73) defined a prediction equation "as the mathematical relationship between a dependent variable and specified independent variables." They pointed out that a term is "effective" in a prediction equation if the ratio of the mean square of the coefficient of the variate to the residual mean square is greater than unity. They justified this statement on the basis that if the ratio were unity or less, it could be assumed that the variation which was accounted for by this term was part of the same random variation as that which appeared in the residual sum of squares. If either a linear or a quadratic term was effective in a yield prediction equation, then both terms would be retained.

Hader et al. (24) stated that as long as a variable has an agronomic basis and satisfies an equation model, the coefficients estimated by the method of least squares are the best estimates that are available from the data. Walker and Pesek (73) justified the retention of statistically insignificant coefficients of variates in a multiple regression equation on this basis.

The most logical basis for dropping a variable from a system lies in the extent to which the yield estimates and their standard errors are changed by its omission (21). Thus, when deciding to delete a variable, all terms, or at least all terms of a given order involving this variable, should be considered as a group.

Thompson (66) utilized a refined statistical approach to determine corn and soybean yields in Illinois, Indiana, Iowa, Missouri, and Ohio for the years 1930 to 1962. His techniques centered around multiple regression analysis which included the following variables; preseason precipitation (from September to May inclusive); May temperature; June temperature; July rainfall; July temperature; August rainfall; and August temperature. Rainfall and temperature interactions were considered for each summer month. He found that the weather variables were related to yields of both soybeans and corn in a curvilinear manner, with July rainfall and August temperature being the most significant weather variables.

It is obvious from previous work that agronomists have long recognized the importance of weather and soil effects on crop yields. Attempts to express these relationships in terms of mathematical models have met with varying degrees of success because of the complexity caused by combinations of so many variables. The most desirable approach to solving the problem would be to evaluate the effect of every combination of weather factors on yield throughout the growing season. At the present time, this is impractical; however, it appears that the most reasonable approach is to estimate the effects of a limited number of the most relevant climatic and soil factors (27).

Cady and Allen (13) analyzed yield data from 72 experiments and used the study as a basis for predicting future yields. Uncontrolled variables such as site differences were measured and included with controlled variables in their analysis. The authors compared a new procedure, prediction sum of squares (PRESS) and commonly used methods of predicting yield. They reported that PRESS gave an estimated prediction equation with a minimal number of predictor variables, including few interaction variables. They found by using the new procedure a 30 percent reduction in the sum of squared deviations between the observed and predictions as compared with the regression method.

Carmer and Swanson (14) studied five procedures for pairwise multiple comparisons of treatment means using computer simulation techniques. Procedures studied were: (a) LSD; (b) use of a preliminary F test with the least significant difference, FLSD; (c) Tukey's Significant Difference, TSD; (d) Duncan's Multiple Range Test, DMRT; and (e) a relatively new Bayesian modification of the least significant difference, BLSD. The authors concluded from results based on simulation of 6,000 experiments involving three, four, six, or eight replicates of either ten or twenty treatments that FLSD, DMRT, and BLSD are more appropriate for use in research than LSD or TSD. Carmer and Swanson stated, "Based on the statistical properties observed in this study a choice among the FLSD, DMRT, and BLSD is difficult; however, the FLSD may be preferred due to its familiarity to researchers and its simplicity of application."

CHAPTER III

METHODS AND PROCEDURES

I. GENERAL INFORMATION

The experiments reported here were conducted over a period of five years at six locations in Tennessee, representing a wide range of climatic conditions and 12 different soil types. The two soil types studied at six locations are listed in Table I. Experiments were initiated to determine the effects of soils and environments on the yield components of forage crops grown for silage, greenchop and grain.

During the years 1965, 1966 and 1967 the following cultivars were planted: 'Tennessee 501' corn; 'RS-610' grain sorghum; and 'Tracy' forage sorghum. Those seeded in 1968 and 1969 were 'Funk's 4831' corn, 'AKS-614' grain sorghum and 'DeKalb FS-22' forage sorghum. 'Sudax SX-11', a sorghum hybrid and 'Gahi-1' pearlmillet were planted in all years.

The two seeding dates of the crops on each of the two soil types at each location are tabulated in Table II. Plant populations were adjusted to approximately 44,500 plants/ha of corn, 55,600 plants/ha of forage and grain sorghum and 111,200 plants/ha of Sudax SX-11 and Gahi-1 pearlmillet from seeding rates which originally resulted in higher populations.

Recommended N applications were broadcast before planting at a rate of 112 to 168 kg/ha. University of Tennessee fertilizer recommendations based on soil test results for high yields were followed for P and

TABLE I

LOCATIONS AND SOIL TYPES ON WHICH EXPERIMENTS WERE CONDUCTED

Location	Soil Type	Horizon	Depth	Code Used in Mnemonic Names for Variables
			cm	
Knoxville	Sequoia	Ap	0-15	1
		A1-B1	15-24	2
		IIB2t-A1	24-38	3
	Sequatchie	Ap	0-28	1
		B1	28-38	2
		B21t	38-64	3
Springfield	Dickson	Ap	0-30	1
		B21t	30-56	2
		B'21tx	56-76	3
	Huntington	Ap	0-28	1
		B21	28-43	2
		B22	43-64	3
Martin	Grenada	Ap1	0-15	1
		Ap2	15-30	2
		B21	30-56	3
	Collins	Ap	0-15	1
		IIA1	15-30	2
		IIB1	30-51	3
Spring Hill	Maury	Ap	0-25	1
		B21t	25-53	2
		B22t	53-86	3
	Emory	Ap	0-18	1
		B21t	18-43	2
		B22t	43-61	3
Jackson	Dexter	Ap	0-15	1
		B21t	15-36	2
		B22t	36-61	3
	Loring	Ap1	0-15	1
		Ap2	15-24	2
		B21t	24-46	3
Crossville	Tilsit	Ap	0-13	1
		A3	13-25	2
		B1	25-41	3
	Hartsells	Ap	0-25	1
		B21	25-46	2
		B22	46-71	3

TABLE II

DATES OF PLANTING AT SIX LOCATIONS ACROSS THE STATE, 1965-1969

Location	Year									
	1965 Planting		1966 Planting		1967 Planting		1968 Planting		1969 Planting	
	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Knoxville	May 4	June 10	May 10	June 22	April 18	June 15	May 7	June 20	April 30	June 2
Springfield	. . .	. . .	. . .	. . .	May 10	June 10	May 2	June 7	May 3	June 2
Martin	. . .	. . .	. . .	. . .	May 24	June 19	May 7	June 5	May 2	June 6
Spring Hill	. . .	. . .	. . .	. . .	May 25	June 20	May 2	June 13	May 15	June 6
Jackson	. . .	. . .	. . .	. . .	May 4	June 26	May 22	June 21	May 5	June 2
Crossville	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	May 6	June 5

K. Some of the plots were limed, so as to adjust the pH above 6.5. In addition, the greenchop entries were sidedressed with 67 kg/ha of N after the second harvest.

Cultivation to control weeds was done as often as necessary with a small farm tractor.

A split-plot factorial arrangement of treatments in a randomized complete block design was employed. The main plot treatments consisted of two planting dates. Each split-plot consisted of corn, grain sorghum and forage sorghum which were harvested for silage, and the sorghum hybrid and pearlmillet for greenchop. Another split-plot treatment was added in 1969 consisting of corn grown for grain. Treatments consisting of irrigation and nonirrigation were also conducted on the Sequoia and Sequatchie soils at Knoxville, the Emory and Maury soils at Spring Hill and the Dexter soil at Jackson, in 1969. The moisture level in the soil for the experiments having irrigation treatments was estimated by using the neutron moisture equipment. Furrow irrigation was used in the irrigated treatment at Jackson, overhead sprinklers were used at the other two locations. In all irrigated experiments, water was applied when the soil moisture reached two bar tension.

There were four replications at all locations except at Spring Hill in 1969, where only three were used. Each split-plot (or split-split-plot, where irrigation levels were used) treatment (crop) consisted of three 9.8 m rows, 93 cm apart. The center 2.7 m of the middle row was used for yield measurements. Dry matter yields of stalks, leaves, and grain were measured and expressed in metric tons per hectare. Regrowth of the sorghum was harvested at the end of the season and included in the total yield (see Table XXIII, Appendix).

II. SOILS STUDIED AND SOIL LABORATORY ANALYSES

The genetic horizons of the 12 soil type study of pits adjacent to these experiments, are shown in Table I, page 21. Physical and chemical determinations from only the first three horizons of the soils were included in this study.

Experiments were conducted on the same soil type and site each year. In 1969, an adjoining area was added to accommodate the additional plots required where irrigation treatments were used.

Mechanical analyses of samples from each soil horizon were made to determine the percent sand, silt and clay, using the method described by Kilmer and Alexander (33).

Three clods were obtained from various representative soil horizons within the pits and bulk densities were determined after coating them with plastic, as described by Brasher et al. (10).

Moisture release curves at the one-third bar and 15 bar tensions were determined for soil horizons by using the porous plate and pressure membrane apparatus to determine the available water-holding capacity of the soils (68). The available water-holding capacity of each soil was determined for each horizon permeable to plant roots or to a maximum depth of 165 cm.

Soil chemical determinations included pH measurements, available P and exchangeable K, cation exchange capacity (by NH_4OAc method), exchangeable Na, K, Ca and Mg, and exchange acidity and were obtained by Oonmuang (45). A complete report of the methods used for these determinations was reported by Oonmuang (45).

III. FIELD EXPERIMENTS AND LABORATORY ANALYSES OF PLANT TISSUE

Corn, grain and forage sorghums were harvested at the silage stage. Corn was harvested when 80 to 90 percent of the kernels were dented; the grain and forage sorghums were harvested when the oldest seeds were in the soft dough stage. The crops were cut to a uniform stubble height of 15 cm. The sorghum hybrid and pearlmillet were harvested for greenchop when the plants reached a height of about 75 cm. Dry matter yields for all component parts were computed after harvesting and drying the forage at 70^{o} C for 36 or more hours. The material was weighed to the nearest gram. In 1969, Manning collected and analyzed corn and grain sorghum tissue samples for N, P, K, Ca and Mg analyses. The values of determinations are from Manning's unpublished thesis (39). N concentrations in the plant tissue were determined by a modification of the Gehrke et al. procedure (21) adapted to the Technicon Autoanalyzer. A modification of the wet oxidation procedure by Gieseking et al. (22) was used to digest all tissue samples for P, K, Ca and Mg. Concentrations of the digestate were determined, using the Technicon Autoanalyzer in a slight modification of the procedure of Steckel and Flannery (63). All laboratory analyses were then converted to percent content of each element. Total uptake of N, P, K, Ca and Mg was calculated by multiplying percent of each element by dry matter yield per hectare.

In 1969, corn was also harvested for grain in separate plots. Grain yield per hectare was adjusted to 15.5 percent moisture.

IV. SOIL MOISTURE MEASUREMENTS

A neutron scattering method similar to that of Gardner and Kirkham (20) was used to determine the soil water content in 1969. Aluminum access tubes five cm in diameter were placed in the soil to a depth of 137 cm in corn and grain sorghum plots for each planting date at all locations except Springfield. The soil moisture contents of two replications were determined at 15 cm intervals to a depth of 137 cm or to bedrock if the soil was shallower than 137 cm. The surface moisture to a depth of 23 cm was recorded, using the surface moisture probe. A detailed description of the working of these instruments has been given by Kuranz (36).

Water use during each two week period was determined by taking the difference in moisture in the soil profile between two successive readings and adding any rainfall and/or irrigation water received during the interval. The total accumulated difference for each tube divided by the number of days in the period was taken to be the daily water used by the particular cultivar.

V. WEATHER RECORDS AND OBSERVATIONS

Daily maximum and minimum temperatures and daily precipitation were used in establishing the yield probabilities at each location. These measurements were obtained from U. S. Weather Service or Tennessee

Agricultural Experiment Station records at or near the experimental sites at stations known in U. S. Weather Service publications as:

Knoxville Plant Science Farm, Knoxville;

Highland Rim Experiment Station, Springfield;

University of Tennessee at Martin, Martin;

Neapolis, near Spring Hill;

West Tennessee Experiment Station, Jackson; and

Plateau Experiment Station, Crossville.

Daily mean temperatures were used as a basis for calculating the degree-days for the period of growth of the plants at each location each year. To correct for excessively high or low temperatures which contribute little to plant growth and development, different heat unit summations were calculated by using ceiling temperatures of 24°, 27°, 29°, 32°, 35°, 38° and base temperatures of 10° and 13° C.

Degree-days were calculated by days for the growing season each year by using all possible combinations of these ceiling and base temperatures. Heat units accumulated during the growing season were then correlated with the total dry matter yields of each crop. On the basis of multiple regression analyses, the 32° C ceiling and 10° C base temperatures were selected as the best predictors of the thermal climates encountered by the forage crops for the years of the study.

The formula employed for calculating effective heat units for the 10° C base - 32° C ceiling system was:

if $(T + t) / 2 \leq 10^{\circ}$ C, then ehu = 0;

if $T \geq 32^{\circ}$ C, then ehu = $[(T + t) / 2] - (T - 32^{\circ}) - 10^{\circ}$;

if $T < 32^{\circ}$ C, then ehu = $(T + t) / 2 - 10^{\circ}$,

where T = maximum temperature and t = the minimum temperature of the day for which the effective heat unit (ehu) was calculated.

Daily precipitation was summed with supplemental water (irrigation) for each month and entered into the soil moisture regime balance. The method consisted of calculating a daily balance of soil moisture available to plants in the root zone. The available water-holding capacity of the soil was assumed to be that moisture between one-third and 15 bar tension to a depth which would allow root penetration (or a maximum depth of 165 cm). The period chosen was May through September, with the assumption that the amount of available water in the root zone was at a maximum value at the beginning of the season. Therefore, a new balance was computed each day by adding any rainfall or supplemental water that occurred and subtracting the estimated amount of evapotranspiration. Two restrictions were observed: (a) the upper limit should never exceed the maximum available water-holding capacity of the soil; and (b) the lower limit should never be less than zero.

Estimated values of evapotranspiration were calculated by use of the formula proposed by Thornthwaite (67). These values were correlated with dry matter yields for each year. In 1969, evapotranspiration values for June, July, August, and September were determined from the neutron scattering measurements. The estimated values during these months correlated as well but no better with dry matter yields than did evapotranspiration. Since evapotranspiration values were available for 1969 only, estimated evapotranspiration values were used for all years in this study.

VI. STATISTICAL METHODS AND PREDICTION EQUATIONS

Soil, evapotranspiration, and yield data were tabulated and recorded on computer cards. Analyses of variance were calculated for each experiment to estimate the effects of years, planting dates, soil types, locations, and irrigation (where involved) on dry matter production. In addition, an analysis of variance of the combined data for all locations was run to estimate differences among crops subjected to different environments. The term "different" as used in this study will refer to significance at a probability level less than or equal to 0.05. Harvey's Least-squares and Maximum Likelihood General Purpose Program (25) was used for the analysis of variance of yield data.

Production is a function of various factors, some of these being soil physical and chemical properties, precipitation, temperature, fertilization practices, and plant densities. Residual variances of yield data from crop-soil-planting data subgroups were inspected. Analyses across locations were deemed appropriate and the yield data were assumed to be normally distributed. Thus, no transformation of any data was attempted. Selection of an appropriate mathematical model that adequately describes biological relationships is extremely important. The incorporation of certain factors into a model was determined by the judgment of the investigator. The Statistical Analysis System (SAS), developed by Barr and Goodnight (3) was used in the multiple regression analyses to assist in selecting appropriate independent variables. In the preliminary analyses, models included regression of yield on every subset of independent terms used in this study (i.e., on each one singly, on every pair, on every triplet, and so on) in an effort to determine the appropriate terms to employ in the final models.

Preliminary multiple regression analyses for yield data of each crop involved all soil variables. In another type of preliminary analysis, the climatic variables and their interactions were estimated as to their usefulness in explaining the variation in yield of each crop. Variables and their interactions were deleted on the basis of their lack of contribution to the prediction equation. In a few cases, dependency was such that the matrix was singular and could not be inverted. When this occurred, the particular variable causing difficulty was identified and deleted from further analyses. Subsequently, the final models were formulated on the basis of the contribution made by the independent variables and their interactions.

Included in the final models, Model I and Model II, were those independent terms and their interactions which were meaningful in explaining variation in the dependent variable. In the judgment of the researcher, a probability level less than or equal to 0.20 was established as indicating sufficient contribution for inclusion in the final models. In case the quadratic term showed significance, the linear term was not deleted from either Model I or Model II. Ordering of independent terms in the combined analysis was based on the ranked values of the standard partial regression coefficients in previous models.

In the final analyses, two models were employed and evaluated as to their relative usefulness in estimating the variation in yield of each crop. Model I involved 20 independent soil variables which can be measured relatively easily and required only moderate scientific expertise, i.e., percent sand, percent silt, and pH. Model II employed 25 soil variables, where substitution was made for certain independent soil variables in Model I by more sophisticated measurements. Percent sand and silt, and pH in Model I were assessed and described by bulk density and base saturation in Model II, respectively. Available P and exchangeable K in the first three horizons were also included in Model II. Sixteen climatic terms were fitted in each model. Thus, the final models will be referred to throughout this study as Model I for those regression equations having some soil variables which can be evaluated faster and in a less costly manner than those in Model II, whereas the modified Model I analyses involving certain soil variables more difficult to measure will be referred to as Model II.

CHAPTER IV

RESULTS AND DISCUSSION

I. INTERACTIONS BETWEEN SOIL TYPES AND ENVIRONMENT AND THEIR EFFECT ON YIELD AND ASSOCIATED CHARACTERISTICS OF CERTAIN FORAGE CROPS

Statistical data and analyses related to crop yields, soil types, planting dates and moisture supply are presented in Tables III through IX and in the Appendix, Tables XIV through XXIII. The two soils at each of the six locations were selectively "paired" for their expected differences in soil moisture-plant relationships during a year with average rainfall and temperature. "Pairings" at each location may be noted in Table I, page 21, the soil listed first at each location having the lower available water holding capacity of the two.

Soil Type

Yields and associated characteristics of corn grown for grain, grain sorghum, forage sorghum, corn silage, Sudax SX-11, and Gahi-1 varied from year to year. Although differences were observed among years and between the two soil types at each location, yields at any one location generally were higher for that soil having a higher moisture supplying capacity (Tables XIV through XX, Appendix). Exceptions to this pattern occurred at Crossville in 1969 where higher corn silage yield and grain percentage (Table XIV and Table XV, Appendix) and higher Sudax SX-11 yield were produced on Tilsit than on Hartsells (Table XVIII

TABLE III

AVERAGE YIELDS OF CORN SILAGE, GRAIN SORGHUM, AND FORAGE SORGHUM, AND GRAIN PERCENTAGES, OBTAINED ON TWO DATES AT SIX LOCATIONS INVOLVING 12 DIFFERENT SOIL TYPES, 1965-1969

Location	Crop	Planting Date							
		Early				Late			
		Total Yield	Grain	Total Yield	Grain	Total Yield	Grain	Total Yield	Grain
		t/ha	percent	t/ha	percent	t/ha	percent	t/ha	percent
		Sequoia		Sequatchie		Sequoia		Sequatchie	
Knoxville (5 year ave.)	Corn silage	9.03	40.3*†	14.30	43.7‡§	6.54	30.3*†	8.96	39.9
	Grain sorghum	8.15	18.2*	11.29	16.0‡	5.47	22.5*	7.32	20.8
	Forage sorghum	12.07	20.1*	17.24	13.8‡	9.18	24.0*	12.84	15.5
		Dickson		Huntington		Dickson		Huntington	
Springfield (3 year ave.)	Corn silage	16.54	29.2*†	24.55	45.2§	16.66	26.9*†	21.47	41.8
	Grain sorghum	12.46	20.4*†	13.59	19.2§	11.35	20.4*†	13.93	26.6
	Forage sorghum	21.93	16.9*†	30.95	12.0§	24.29	12.7*†	24.05	33.1
		Grenada		Collins		Grenada		Collins	
Martin (3 year ave.)	Corn silage	16.73	44.7	16.05	41.5‡§	13.07	36.2	13.55	40.0
	Grain sorghum	13.71	17.8†	15.81	14.4‡§	12.74	21.7†	12.01	20.8
	Forage sorghum	22.90	15.5*	28.39	14.2‡	17.49	20.7*	19.11	17.3
		Maury		Emory		Maury		Emory	
Spring Hill (3 year ave.)	Corn silage	10.17	38.8*†	14.79	42.3‡	9.17	31.5*†	12.64	45.7
	Grain sorghum	8.82	20.2*†	11.40	18.8‡§	7.02	19.3*†	10.05	15.4
	Forage sorghum	15.07	15.0*†	21.81	13.3‡§	13.11	14.6*†	16.64	12.8
		Dexter		Loring		Dexter		Loring	
Jackson (3 year ave.)	Corn silage	9.95	35.5*	11.57	36.6‡	8.10	38.6*	8.71	39.5
	Grain sorghum	10.24	23.7	9.71	25.4‡	7.57	31.6	8.89	31.4
	Forage sorghum	14.20	22.1*†	15.59	26.0‡§	12.64	26.3*†	14.23	18.8

TABLE III (continued)

Location	Crop	Planting Date							
		Early				Late			
		Total Yield	Grain	Total Yield	Grain	Total Yield	Grain	Total Yield	Grain
		t/ha	percent	t/ha	percent	t/ha	pereent	t/ha	percent
		Dexter		Loring		Dexter		Loring	
Jackson (3 year ave.)	Corn silage	9.95	35.5*	11.57	36.6‡	8.10	38.6*	8.71	39.5
	Grain sorghum	10.24	23.7	9.71	25.4‡	7.57	31.6	8.89	31.4
	Forage sorghum	14.20	22.1*†	15.59	26.0‡§	12.64	26.3*†	14.23	18.8
		Tilsit		Hartsells		Tilsit		Hartsells	
Crossville (1 year)	Corn silage	17.01	42.6*†	14.01	35.5‡§	14.23	38.0*†	12.23	29.9
	Grain sorghum	10.87	14.6	12.15	11.2‡§	13.97	24.0	12.93	20.6
	Forage sorghum	13.47	18.2	15.47	15.9§	14.91	19.0	15.38	19.4
General Mean	Corn silage	13.24	38.5	15.88	40.8	11.30	33.6	12.93	39.5
	Grain sorghum	10.71	19.2	12.33	17.5	9.68	23.3	10.85	22.6
	Forage sorghum	16.61	18.0	22.24	15.9	15.27	19.6	17.04	19.5

* = Mean difference between total yields on the two soils at both planting dates for a given location, $P < .05$.

† = Mean difference between percent grain on the two soils at both planting dates for a given location, $P < .05$.

‡ = Mean difference between total yields from early and late planting on both soils at a location, $P < .05$.

§ = Mean difference between percent grain produced from early and late planting on both soils at a location, $P < .05$.

TABLE IV

EFFECTS OF SUPPLEMENTAL IRRIGATION AND SOIL TYPE ON AVERAGE YIELDS OF CORN SILAGE, GRAIN SORGHUM AND FORAGE SORGHUM, AND PERCENT GRAIN, AT THREE LOCATIONS, 1969

Location	Crop	Nonirrigated Soil Type				Irrigated Soil Type			
		Total Yield	Grain	Total Yield	Grain	Total Yield	Grain	Total Yield	Grain
		t/ha	percent	t/ha	percent	t/ha	percent	t/ha	percent
		Sequoia		Sequatchie		Sequoia		Sequatchie	
Knoxville	Corn silage	8.48	31.2	12.22	44.2‡	12.94	41.8	11.63	40.4
	Grain sorghum	9.95	18.3	10.90	17.0	11.26	18.0	11.79	12.9
	Forage sorghum	15.33	24.9	18.04	24.0	18.10	20.4	20.94	17.7
		Maury		Emory		Maury		Emory	
Spring Hill	Corn silage	9.74	26.8*†	14.57	45.3	12.71	39.6*†	15.77	42.1
	Grain sorghum	9.28	21.4*†	12.43	17.3‡	11.89	16.7*†	14.02	15.6
	Forage sorghum	14.22	18.1†	21.92	14.5‡§	24.48	16.7†	24.89	15.7
		Dexter				Dexter			
Jackson	Corn silage	8.34	38.1‡§	. .	. .	12.47	48.0	. .	. .
	Grain sorghum	10.97	26.2	. .	. .	12.04	24.1	. .	. .
	Forage sorghum	18.23	26.7§	. .	. .	17.89	25.4	. .	. .
General Mean	Corn silage	8.85	32.0	13.39	44.8	12.71	43.1	13.70	41.3
	Grain sorghum	10.07	22.0	11.67	17.2	11.73	19.6	12.90	14.3
	Forage sorghum	15.92	23.2	19.98	19.3	20.16	20.8	22.91	16.7

* = Difference between the two soils within a location for total yield, P < .05.

† = Difference between the two soils within a location for percent grain, P < .05.

‡ = Difference in irrigated and nonirrigated treatment effects on total yield within a location, P < .05.

§ = Difference in irrigated and nonirrigated treatment effects on percent grain within a location, P < .05.

TABLE V

EFFECTS OF SUPPLEMENTAL IRRIGATION AND PLANTING DATES ON AVERAGE YIELDS OF CORN SILAGE, GRAIN SORGHUM, AND FORAGE SORGHUM AT THREE LOCATIONS, 1969

		Planting Date							
		Early				Late			
		Nonirrigated		Irrigated		Nonirrigated		Irrigated	
Location	Crop	Total Yield	Grain	Total Yield	Grain	Total Yield	Grain	Total Yield	Grain
		t/ha	percent	t/ha	percent	t/ha	percent	t/ha	percent
Knoxville	Corn silage	13.59	38.8*	15.04	39.3‡§	7.11	39.4*	9.53	44.1
	Grain sorghum	12.51	12.6	12.45	11.8‡	8.34	25.2	10.60	19.5
	Forage sorghum	22.74	18.6	24.60	18.8‡§	10.62	22.7	14.44	19.3
Spring Hill	Corn silage	12.57	37.0	14.14	39.0	11.73	38.9	14.34	43.0
	Grain sorghum	11.57	20.4*	11.62	18.9§	10.14	17.5*	14.28	13.8
	Forage sorghum	20.31	14.7*†	26.40	12.7‡	15.83	17.4*†	22.96	15.1
Jackson	Corn silage	7.38	26.7*†	11.49	45.4‡§	9.31	46.9*†	13.46	50.2
	Grain sorghum	13.12	19.2	14.64	17.2‡§	8.82	36.7	9.44	34.7
	Forage sorghum	19.05	26.1†	19.30	25.2§	17.41	27.4†	16.47	25.6
General Mean	Corn silage	11.18	34.2	13.55	41.2	9.38	41.7	12.44	45.8
	Grain sorghum	12.40	17.4	12.90	16.0	9.10	26.5	11.44	22.7
	Forage sorghum	20.70	19.8	23.44	18.9	14.62	22.5	17.96	20.0

* = Difference between total yields from nonirrigated and irrigated treatments within planting date, $P < .05$.

† = Difference between percent grain from nonirrigated and irrigated treatments within planting date, $P < .05$.

‡ = Difference in total yield between early and later plantings without regard to moisture levels, $P < .05$.

§ = Difference in percent grain between early and later plantings without regard to moisture levels, $P < .05$.

TABLE VI

YIELDS OF CORN FOR GRAIN SEEDED ON TWO DATES AT SIX LOCATIONS INVOLVING 12 DIFFERENT SOIL TYPES, 1969

Location	Soil Type		Planting Date Early		Late
			--------100 kg/ha-------		
Knoxville	Sequoia		47.4	†	40.7
	Sequatchie		88.0		21.9
Springfield	Dickson	*	60.1	†	49.6
	Huntington		170.2		141.0
Martin	Grenada	*	92.5		57.0
	Collins		122.3		101.9
Spring Hill	Maury	*	62.2		36.3
	Emory		90.2		95.6
Jackson	Dexter		39.8		57.3
	Loring		59.2		53.2
Crossville	Tilsit		66.0		63.4
	Hartsells		65.0		58.4
General Mean			80.2		64.7

* = Difference in yield between early and late planting across both soils within a location, $P < .05$.

† = Difference in yield between the two soils at the specified location, $P < .05$.

TABLE VII

AVERAGE YIELDS OF SUDAX SX-11 AND GAHI-1, AND PERCENT YIELD PRODUCED AFTER AUGUST 1 FROM PLANTS SEEDED ON TWO DATES AT SIX LOCATIONS INVOLVING 12 DIFFERENT SOIL TYPES, 1965-1969

Location	Crop	Planting Date							
		Early				Late			
		Total Yield	After Aug. 1	Total Yield	After Aug. 1	Total Yield	After Aug. 1	Total Yield	After Aug. 1
		t/ha	percent	t/ha	percent	t/ha	percent	t/ha	percent
		Sequoia		Sequatchie		Sequoia		Sequatchie	
Knoxville	Sudax SX-11	6.70	47.2*†	9.04	50.7‡§	5.16	82.3*†	6.83	81.3
(5 year ave.)	Gahi-1	7.10	51.3*	9.29	41.7‡§	6.10	87.5*	6.13	78.6
		Dickson		Huntington		Dickson		Huntington	
Springfield	Sudax SX-11	7.49	33.4*†	5.92	34.5§	7.06	53.9*†	5.92	50.8
(3 year ave.)	Gahi-1	7.04	39.7*	7.42	40.9§	6.56	55.3*	7.51	51.6
		Grenada		Collins		Grenada		Collins	
Martin	Sudax SX-11	7.86	35.3*†	9.72	39.5‡	6.03	52.4*†	7.55	46.9
(3 year ave.)	Gahi-1	9.47	44.3†	8.54	41.2‡	6.80	52.8†	6.91	49.7
		Maury		Emory		Maury		Emory	
Spring Hill	Sudax SX-11	8.08	49.5*	9.01	38.9‡§	6.45	82.8*	7.08	74.7
(3 year ave.)	Gahi-1	7.61	52.0	7.78	45.9‡§	5.76	86.9	6.27	80.6
		Dexter		Loring		Dexter		Loring	
Jackson	Sudax SX-11	6.02	42.3*	7.11	38.8‡§	4.80	61.2*	5.72	54.0
(3 year ave.)	Gahi-1	5.99	41.7*	6.63	38.8‡§	5.31	62.1*	5.36	57.5

TABLE VII (continued)

		Planting Date							
		Early				Late			
Location	Crop	Total Yield	After Aug. 1	Total Yield	After Aug. 1	Total Yield	After Aug. 1	Total Yield	After Aug. 1
		t/ha	percent	t/ha	percent	t/ha	percent	t/ha	percent
		Tilsit		Hartsells		Tilsit		Hartsells	
Crossville (1 year)	Sudax SX-11	13.68	36.3*	11.74	36.4‡§	9.09	35.0*	7.26	41.1
	Gahi-1	6.33	17.9†	7.77	36.9§	7.19	35.7†	8.04	37.8
General Mean	Sudax SX-11	8.30	39.8	8.76	40.0	6.43	58.8	6.73	58.1
	Gahi-1	7.26	41.9	7.90	41.0	6.28	62.1	6.75	57.9

* = Mean difference in total yields from the two soils at both planting dates for a given location, $P < .05$.

† = Mean difference in after-August 1 yields from the two soils at both planting dates for a given location, $P < .05$.

‡ = Mean difference between total yields from early and late planting on both soils at a location, $P < .05$.

§ = Mean difference in after-August 1 yields from early and late plantings on both soils at a location, $P < .05$.

TABLE VIII

EFFECTS OF SUPPLEMENTAL IRRIGATION AND SOIL TYPE ON AVERAGE YIELDS OF SUDAX SX-11 AND GAHI-1, AND PERCENT YIELD PRODUCED AFTER AUGUST 1, AT THREE LOCATIONS, 1969

		Nonirrigated Soil Type				Irrigated Soil Type			
Location	Crop	Total Yield	After Aug. 1	Total Yield	After Aug. 1	Total Yield	After Aug. 1	Total Yield	After Aug. 1
		t/ha	percent	t/ha	percent	t/ha	percent	t/ha	percent
		Sequoia		Sequatchie		Sequoia		Sequatchie	
Knoxville	Sudax SX-11	6.32	56.2	6.07	51.5	6.67	43.6	6.28	49.3
	Gahi-1	6.56	55.8*	6.39	54.6	7.30	46.5*	6.34	54.3
		Maury		Emory		Maury		Emory	
Spring Hill	Sudax SX-11	9.40	63.1	9.98	52.8	9.46	63.6	11.10	47.3
	Gahi-1	9.22	62.3†	8.78	54.1	9.06	66.5†	8.76	51.7
		Dexter				Dexter			
Jackson	Sudax SX-11	6.41	53.5	. .	. .	7.29	46.4	. .	. .
	Gahi-1	6.91	44.5	. .	. .	7.23	40.8	. .	. .
General Mean	Sudax SX-11	7.38	57.6	8.03	52.1	7.81	51.1	8.69	48.3
	Gahi-1	7.56	54.2	7.59	54.3	7.87	51.2	7.55	53.0

* = Difference between the two soils within a location for total yield, $P < .05$.

† = Difference between the two soils within a location for production after August 1, $P < .05$.

TABLE IX

EFFECTS OF SUPPLEMENTAL IRRIGATION AND PLANTING DATES ON AVERAGE YIELDS OF SUDAX SX-11 AND GAHI-1, AND PERCENT YIELD PRODUCED AFTER AUGUST 1, AT THREE LOCATIONS, 1969

		Planting Date							
		Early				Late			
		Nonirrigated		Irrigated		Nonirrigated		Irrigated	
Location	Crop	Total Yield	After Aug. 1	Total Yield	After Aug. 1	Total Yield	After Aug. 1	Total Yield	After Aug. 1
		t/ha	percent	t/ha	percent	t/ha	percent	t/ha	percent
Knoxville	Sudax SX-11	6.77	42.8	7.08	37.6*†	5.62	67.2	5.87	56.9
	Gahi-1	6.56	40.6	7.34	42.2*†	6.39	70.2	6.30	59.3
Spring Hill	Sudax SX-11	10.18	48.9	12.11	51.5*	9.21	67.6	8.46	59.6
	Gahi-1	10.14	46.5	9.50	49.4*†	7.86	73.5	8.32	70.4
Jackson	Sudax SX-11	7.08	41.3	7.88	37.6	6.63	58.7	5.65	51.9
	Gahi-1	7.48	36.5	7.34	32.2†	6.35	50.2	7.11	4918
General Mean	Sudax SX-11	8.01	45.0	9.02	43.8	7.15	64.7	6.66	56.6
	Gahi-1	8.06	41.8	8,06	42.0	6.87	65.3	7.25	60.4

* = Difference in total yield between early and late plantings without regard to moisture levels, $P < .05$.

† = Difference in yield after August 1 between early and late plantings without regard to moisture levels, $P < .05$.

and Table XIX, Appendix). The lower yield on Hartsells may have been due to lower pH values and lower levels of P, K, Ca and Mg on the Hartsells than on Tilsit (39).

Grain production in grain sorghum and after-August 1 yield of Gahi-1 were higher on Grenada than on Collins (Table XVIII and Table XIX, Appendix). In 1968, yields were reduced by extremely dry weather, since essentially no rain fell during the last ten weeks of the growing season. The higher yield on Grenada was attributed to increased efficiency of available moisture in this fragipan soil.

Another exception from the three-year average total yield and after-August 1 yield component of Sudax SX-11 was noted in greater production from Dickson than Huntington (Table VII, page 38).

Planting Date

Early planted crops consistently had higher total dry matter production than those planted later. The only exception was noted in the one-year experiment at Crossville (Table III, page 33) where a higher grain sorghum yield was realized from the late seeding. A higher yield for the late planting could be attributed to young and vigorous plants which responded to favorable temperatures and adequate rainfall during the critical growth period in 1969.

Grain yield of corn silage, grain sorghum and forage sorghum from the first planting were usually higher than those from the second planting. These results are in agreement with the generally accepted view that reduced yields are associated with delayed plantings because of moisture supply distribution and related short-term plant-moisture stresses. Griffith (23) reported that May-planted corn in Indiana reflected a nine percent increase in total dry matter production and an 11 percent increase in grain content over that planted in June.

Conversely, after-August 1 yields of Sudax SX-11 and Gahi-1 generally were higher with the four to six week delay in seeding. The data suggest that total yield produced at most locations was greater for the May plantings than for June. However, Sudax SX-11 and Gahi-1 production after August 1 was greater from the June plantings. Thus, it appears that the "greenchop" crops are capable of producing high yields of forage under adverse conditions, such as limited moisture supplies and high temperatures which normally occur in the middle and latter part of the growing season.

<u>Moisture Supply</u>

Even though rainfall during the 1969 growing season was generally favorable for high yields, irrigation increased corn yields at Knoxville and Jackson. Percent grain in corn silage at Jackson was also higher for the irrigated plot than for the nonirrigated. Total dry matter production of grain and forage sorghums was increased by irrigation at Spring Hill. In addition, the grain component of forage sorghum production at Spring Hill was higher for the irrigation treatment than for the nonirrigation treatment. Generally, maximum growth of corn silage, grain sorghum and forage sorghum could not be sustained with natural soil moisture and precipitation during the 1969 growing season.

In contrast, supplemental irrigation in 1969 did not increase the yield of Sudax SX-11 or Gahi-1 (Table IX, page 41). The response of Sudax SX-11 and Gahi-1 to natural precipitation indicated that soil moisture in 1969 was not limiting crop production for these two forages. This yield relationship to plant environment remained the same for both plantings at the three locations. The conclusion is that corn, grain sorghum and forage sorghum have greater demands for moisture than Sudax SX-11 and Gahi-1. Stated another way, the variation in total dry matter production of Sudax SX-11 and Gahi-1 was less than the three silage crops across the environments encountered.

II. NUTRIENT UPTAKE BY CORN AND GRAIN SORGHUM

The data for total (seasonal) uptake of N, P, K, Ca and Mg in the above-ground parts of corn and grain sorghum planted on two dates and two soil types at each location are presented in Table X, and the corresponding analyses of variance in the Appendix, Table XXIV.

Soil Type

In the nonirrigated experiments, the two soil types at each of the six locations generally showed no difference in nutrient uptake in the above-ground portions of corn silage and grain sorghum. In the nonirrigated treatments, only Mg uptake varied with soil type. Grain sorghum harvested from the nonirrigated Emory soil was higher in Mg than that from Maury. Exchangeable Mg in the Emory soil was higher throughout the profile than it was in the Maury (45). This increased removal of Mg arose from both higher dry matter yields and higher percentages of Mg in the plant tissue.

TABLE X

NUTRIENT UPTAKE OF CORN SILAGE AND GRAIN SORGHUM FROM PLANTS SEEDED ON TWO DATES AT SIX LOCATIONS INVOLVING 12 DIFFERENT SOIL TYPES, 1969

Location	Soil	Planting Date	Corn¶					Grain Sorghum¶				
			Ca	Mg	K	P	N	Ca	Mg	K	P	N
			kg/ha					kg/ha				
Knoxville	Sequoia		24.4	33.0	76.6	13.6	130.2	27.1	28.0	113.0	20.7	136.6
	Sequatchie		36.9	48.8	98.4	28.0	153.4	34.9	39.9	98.9	24.8	166.6
		Early	45.0	55.4	117.4	27.3	175.5	35.4	38.4	124.0	27.7	154.8
		Late	16.3	25.9	57.7	14.3	108.2	26.7	29.4	87.9	17.8	148.4
Knoxville	Sequoia*		36.8	43.3	133.5	18.8	148.0	30.5	29.4†	132.2	21.6	161.0
	Sequatchie*		32.8	40.6	97.4	22.5	137.4	34.5	36.5	115.4	24.4	161.9
		Early	45.2§	54.1§	145.7§	25.4	164.5	32.3	33.5	127.3	25.8§	165.9
		Late	24.4	29.8	85.2	15.9	120.9	32.7	32.5	120.2	20.2	157.0
Springfield	Dickson		65.0	50.4	210.4	32.2	267.4	43.9	30.2	172.9	23.7	180.5
	Huntington		78.5	69.4	243.0	59.0	385.3	74.9	47.6	195.6	36.8	229.5
		Early	69.2	57.0	260.7	47.2	304.9	56.4	34.5	197.5§	31.1	183.5
		Late	74.3	62.8	192.7	44.1	347.7	62.4	43.3	171.0	29.4	226.5
Martin	Grenada		31.7	43.7	162.5	30.8	163.6	29.1	47.2	113.4	30.3	164.1
	Collins		34.4	42.4	183.3	36.9	194.0	50.3	47.8	226.8	42.7	198.2
		Early	33.0	42.6	168.4	33.5	172.4	44.5	48.6	153.8	37.1	169.3
		Late	33.0	43.5	177.5	34.2	185.2	34.9	46.4	186.3	35.8	193.1
Spring Hill	Maury		23.0	28.4	111.3	20.0	188.2	25.4	24.6†	105.3	18.8	135.2
	Emory		42.3	42.0	118.3	28.4	202.8	46.6	34.7	143.9	26.0	161.0
		Early	37.5	39.5	130.0	27.7	208.0	41.6	32.2	131.6	23.8	154.4
		Late	27.9	30.9	106.6	20.7	183.0	30.4	27.1	175.2	21.0	141.8

TABLE X (continued)

Location	Soil	Planting Date	Corn¶ Ca	Mg	K	P	N	Grain Sorghum¶ Ca	Mg	K	P	N
			kg/ha					kg/ha				
Spring Hill	Maury*		30.0†	29.1	143.4†	21.7†	187.4	28.9†	29.9†	151.9	23.4	175.5
	Emory*		43.3	34.1	152.7	34.9	228.3	49.0	39.7	171.6	33.0	176.2
		Early	38.6	34.0	159.4	31.6§	213.4	38.8	34.1	128.1	23.5	163.9
		Late	34.6	29.3	136.6	24.9	202.3	39.0	35.6	195.5	33.0	187.8
Jackson	Dexter		22.9	21.4	116.5	18.8	123.1	47.9	38.0	127.8	17.9	127.3
	Loring		26.3	26.1	95.6	17.6	139.2	34.4	38.7	130.9	17.9	140.8
		Early	22.9	24.7	105.5	14.7	116.9§	48.2	41.0	137.2	15.8	130.2
		Late	26.3	22.8	106.6	21.7	145.4	34.0	35.6	121.6	20.1	138.0
Jackson	Dexter*		32.6	29.0	151.8‡	26.8	164.3	45.6	38.2	126.2	25.2	143.1
		Early	35.2	29.9	156.5	27.8	156.3	65.6	47.3	141.6§	30.8	153.0
		Late	30.0	28.1	147.2	25.9	172.4	25.6	29.1	110.7	19.7	133.3
Crossville	Tilsit		54.3	25.2	189.1	38.5	249.9	49.5	18.1	173.8	30.7	204.5
	Hartsells		46.2	34.7	149.1	28.8	206.6	33.5	26.5	140.0	26.4	213.9
		Early	48.2	33.1	170.3	36.1	230.0	30.2	20.6	125.0	26.3	190.9
		Late	52.3	26.8	167.9	31.2	226.5	52.9	23.9	188.7	30.7	227.4
Means	All Soils		38.9	37.7	143.5	28.1	192.3	40.3	35.0	143.5	26.1	169.2
		Early	42.0	41.9	157.1	30.3	195.7	42.4	36.1	140.6	26.7	163.5
		Late	35.8	33.6	129.9	25.9	188.9	38.3	33.9	146.4	25.6	174.9

* = Irrigation treatment on soils.

† = Difference in nutrient uptake in forage produced on two soils at a location, $P < .05$.

‡ = Difference in K uptake in forage produced from Dexter irrigated and Dexter nonirrigated, $P < .05$.

TABLE X (continued)

§ = Difference in nutrient uptake in forage produced from early and late plantings at a location, $P < .05$.

¶ = Laboratory analyses for Ca, Mg, K, and P content were obtained by Manning (39).

By considering the uptake of nutrients with respect to soil types with moisture stress removed (irrigated when soil moisture reached two bar tension), uptake of Mg in grain sorghum harvested was higher on Sequatchie and Emory than on Sequoia and Maury. The percent of Mg in forage grown on Sequatchie was higher than that grown on Sequoia. Increased soil moisture resulted in higher P, K, and Ca uptake by corn grown on Emory than that on Maury. More Ca occurred also in grain sorghum forage under irrigation on Emory than on Maury. Oonmuang (45) found that exchangeable Ca greatly decreased with depth in the Maury soil but remained relatively high in the Emory profile. He also found relatively high levels of both available P and exchangeable K in both soils.

Planting Date

Planting date was a very important variable relative to uptake of K, Ca and Mg in the above-ground portion of corn. Under irrigated conditions, planting corn on April 30 at Knoxville resulted in greater uptake of K, Ca and Mg than was the case when the crop was planted on June 2. This difference may be attributed to increased dry matter production from the early planting.

Late planting of grain sorghum at Knoxville and Spring Hill increased both percent P and total uptake of P. More K was removed by grain sorghum from the May 3 planting than when planted June 2 at Springfield. This was due to higher amounts of K in tissues from the early planted crop.

The four-week delay in planting corn on nonirrigated plots at Jackson resulted in increased N removal. Higher N uptake was obtained from the June 2 planting where more total dry matter was obtained than from the May 5 planting.

With adequate available moisture, the planting date at Jackson affected the K uptake by grain sorghum. Analysis of the irrigated grain sorghum plots showed increased K uptake in forage from the early planting. This increase can be attributed to a higher amount of K in the forage harvested early.

Moisture Supply

A comparison of irrigated and nonirrigated treatments at each location generally showed no difference in seasonal uptake of N, P, K, Ca and Mg by corn and grain sorghum. The only exception occurred at Jackson, where on the Dexter soil irrigation resulted in a higher K uptake in corn. The lower K uptake for the nonirrigated treatment may be related to an inadequate water supply (only 22.8 cm of rainfall was received in the months June through August) which resulted in moderation of plant growth.

III. QUANTITATIVE EVALUATION OF SELECTED VARIABLES ON CROP YIELDS

Yields of corn silage, grain sorghum, forage sorghum, Sudax SX-11, and Gahi-1 were measured for 82 location-treatment-years. As described earlier, detailed soil characteristics and climatological conditions were measured in an attempt to explain variation in yield of the five crops. In the preliminary multiple regression analyses a number of independent variables were used. From each of the top three horizons, the following were selected: percent sand; percent silt; percent clay; pH; available P; exchangeable K; exchangeable Ca; exchangeable Mg; bulk density; base saturation; Ca/Mg. In addition, the following terms were used: available water-holding capacity of soil profile (AWHC); evapotranspiration (ET) and precipitation per month during the growing season; time-temperature index (DD):; DD x AWHC; DD x Precipitation; plus ET x ET and DD x DD for each month during the growing season. The legend for the terms used is found in Table XI. The standard partial regression coefficients and R^2 values of Model I and Model II for each crop are presented in Table XII. The final regression equations for Model I and Model II are shown in Table XIII.

One approach to evaluating the relative importance of each variable in a multiple regression equation is to rank the standard partial regression coefficients in order of the sizes of these coefficients, ignoring sign. In this study, the relative importance of the climatic and soil terms in each equation may be obtained by examination of the standard partial regression coefficients as presented in Table XII.

Total Yield of Corn Silage

Results of the regression analyses for corn silage indicate that the linear and quadratic ET in June terms ranked highest among all the terms in explaining variation in yield. Of interest also is the relative importance of precipitation. Both the linear and quadratic terms of the available water-holding capacity of the soil were extremely important.

TABLE XI

KEY TO ABBREVIATIONS OF TERMS USED IN THE VARIOUS REGRESSION EQUATIONS

Abbreviated Term	Definition of Terms
$\hat{Y}$	Total predicted yield of forage crop in metric tons per hectare.
Sand*	Percent sand in the soil horizon.
Silt*	Percent silt in the soil horizon.
Clay*	Percent clay in the soil horizon.
pH*	Soil pH, as determined by a Beckman pH Meter using a soil paste (water-leached method).†
Ca*	Kilograms per hectare of exchangeable calcium (NH_4OAc method).†
Mg*	Kilograms per hectare of exchangeable magnesium (NH_4OAc method).†
P*	Kilograms per hectare of available phosphorus (NH_4OAc method).†
K*	Kilograms per hectare of exchangeable potassium (NH_4OAc method).†
BD*	Bulk density, as described by Brasher et al.
BS*	Base saturation, NH_4OAc method.†
Ca/Mg*	Calcium-magnesium ratio.†
AWHC	Available water-holding capacity expressed in cm, assumed to be moisture content between 1/3 bar and 15 bar tension to a depth not permeable to plant roots or to a maximum depth of 165 cm.
ET	Evapotranspiration in millimeters on a monthly basis.
Prec	Precipitation in millimeters on a monthly basis.
DD	Heat accumulated from planting to harvest using a base temperature of 10^{o} C and a ceiling temperature of 32^{o} C and expressed in degree-days.
DD·AWHC	Interaction term for variables DD and AWHC.
DD·Prec	Interaction term for variables DD and Prec.

*Quantitative evaluations of the variable were made from the top three horizons.

†Source: Oonmuang (45).

TABLE XII

MODEL I AND MODEL II REGRESSION ANALYSES OF YIELD OBSERVATIONS FROM 82 LOCATION-TREATMENT-YEARS FOR CORN SILAGE, GRAIN SORGHUM, FORAGE SORGHUM, GRAIN CONTENT IN CORN SILAGE, SUDAX SX-11 AND GAHI-1 EMPLOYING 16 AND 35 CLIMATIC AND SOIL TERMS, RESPECTIVELY, 1965-1969

	Model I			Model II		
Dependent Variables	Independent Terms†	Standard Partial Regression Coefficients	R^2	Independent Terms†	Standard Partial Regression Coefficients	R^2
Corn Silage (total yield)	Percent Sand (2)*	.23	.741	BD (1)	.34	.730
	Percent Silt (2)	1.13		Mg (1)	.71	
	Mg (1)	.65		K (2)	.83	
	Mg (3)	1.08		AWHC	3.05	
	Ca/Mg (1)	.51		AWHC x AWHC	2.71	
	AWHC	2.43		Prec	3.73	
	AWHC x AWHC	2.76		DD	.02	
	Prec	4.25		DD x DD	1.39	
	DD	.17		DD x Prec	3.50	
	DD x DD	1.53		ET-June	4.11	
	DD x Prec	4.13		ET-June x ET-June	4.60	
	ET-June	4.28		ET-July	.52	
	ET-June x ET-June	4.32		ET-Aug	1.10	
	ET-July	.57		ET-Aug x ET-Aug	1.65	
	ET-Aug	1.07				
	ET-Aug x ET-Aug	1.54				
Corn Silage (percent grain)	Percent Sand (2)	.06	.666	BD (1)	.35	.658
	Percent Silt (2)	1.25		Mg (1)	.47	
	Mg (1)	.34		K (2)	.76	
	Mg (3)	1.04		AWHC	2.52	
	Ca/Mg (1)	.48		AWHC x AWHC	2.32	
	AWHC	2.65		Prec	5.59	
	AWHC x AWHC	2.87		DD	.06	

TABLE XII (continued)

Dependent Variables	Model I			Model II		
	Independent Terms†	Standard Partial Regression Coefficients	R^2	Independent Terms†	Standard Partial Regression Coefficients	R^2
	Prec	5.64		DD x DD	2.35	
	DD	.02		DD x Prec	5.42	
	DD x DD	2.35		ET-June	3.84	
	DD x Prec	5.53		ET-June x ET-June	4.12	
	ET-June	4.25		ET-July	.45	
	ET-June x ET-June	4.19		ET-Aug	1.37	
	ET-July	.53		ET-Aug x ET-Aug	1.49	
	ET-Aug	1.31				
	ET-Aug x ET-Aug	1.43				
Grain Sorghum (total yield)	Percent Sand (2)	.42	.619	BD (3)	.21	.564
	Percent Silt (1)	2.01		Mg (1)	.63	
	Mg (1)	.59		Mg (3)	.44	
	Mg (3)	1.25		P (1)	.27	
	Ca/Mg (1)	.50		K (2)	.73	
	AWHC	2.76		Ca/Mg (1)	.17	
	AWHC x AWHC	5.65		Prec	.97	
	Prec	3.81		Prec x Prec	1.84	
	Prec x Prec	2.59		DD x AWHC	.39	
	DD x AWHC	2.58		DD x Prec	.32	
	DD x Prec	1.83		ET-June	3.08	
	ET-June	4.30		ET-June x ET-June	3.41	
	ET-June x ET-June	4.39		ET-Aug	1.05	
	ET-Aug	1.18		ET-Aug x ET-Aug	1.01	
	ET-Aug x ET-Aug	1.11				
Forage Sorghum (total yield)	Percent Sand (1)	2.49	.555	BD (1)	.77	.538
	Percent Sand (2)	1.55		BD (3)	.97	
	Percent Silt (1)	2.01		Mg (1)	.86	

TABLE XII (continued)

Dependent Variables	Model I Independent Terms†	Model I Standard Partial Regression Coefficients	Model I R^2	Model II Independent Terms†	Model II Standard Partial Regression Coefficients	Model II R^2
	Percent Silt (2)	1.95		BS (1)	.19	
	Mg (1)	.22		P (1)	.21	
	Mg (3)	.70		Ca/Mg (1)	.20	
	Ca/Mg (1)	.46		DD	.00	
	AWHC	1.64		DD x AWHC	.06	
	Prec	.38		DD x Prec	.47	
	DD	.49		ET-June	.72	
	DD x AWHC	1.67		ET-July	.26	
	ET-June	.83		ET-July x ET-July	.84	
	ET-July	.09		ET-Sep	.62	
	ET-July x ET-July	.37		ET-Sep x ET-Sep	.28	
	ET-Aug	.34				
Sudax SX-11 (total yield)	Percent Sand (1)	.59	.537	BD (1)	.35	.536
	Percent Silt (1)	2.75		BD (3)	.74	
	Percent Silt (2)	2.28		Mg (1)	.54	
	Mg (3)	.25		Mg (3)	.43	
	AWHC	.77		P (1)	.16	
	Prec	1.29		AWHC	.59	
	Prec x Prec	1.55		AWHC x AWHC	1.29	
	DD	.36		Prec	1.97	
	ET-June	.25		Prec x Prec	2.24	
	ET-June x ET-June	.48		DD	.31	
	ET-July	.98		ET-June	.47	
	ET-Sep	1.07		ET-July	1.16	
				ET-July x ET-July	.29	
				ET-Sep	.78	
				ET-Sep x ET-Sep	.31	

TABLE XII (continued)

Dependent Variables	Model I: Independent Terms†	Model I: Standard Partial Regression Coefficients	Model I: R^2	Model II: Independent Terms†	Model II: Standard Partial Regression Coefficients	Model II: R^2
Gahi-1	Percent Sand (2)	.60	.473	BD (1)	.39	.500
(total yield)	Percent Silt (2)	.64		BD (3)	.72	
	Mg (1)	.02		Mg (1)	.54	
	AWHC	1.04		Mg (3)	.24	
	Prec	1.99		P (1)	.08	
	Prec x Prec	2.12		AWHC	1.38	
	DD	.18		Prec	1.40	
	DD x AWHC	1.27		Prec x Prec	1.54	
	ET-July	.99		DD	.14	
	ET-Sep	.36		DD x AWHC	1.34	
	ET-Sep x ET-Sep	.87		ET-July	1.64	
				ET-July x ET-July	.83	
				ET-Sep	1.07	

* = Value in parentheses is soil horizon.

† = Values for pH, Ca, Mg, P, K, and BS were determined by Oonmuang (45).

TABLE XIII

MODEL I AND MODEL II (FINAL) REGRESSION EQUATIONS, R^2, $\bar{Y}$, AND STANDARD ERROR OF ESTIMATE FOR CORN SILAGE, GRAIN SORGHUM, FORAGE SORGHUM, GRAIN CONTENT IN CORN SILAGE, SUDAX SX-11 AND GAHI-1 YIELDS EMPLOYING 16 AND 35 CLIMATIC AND SOIL TERMS, RESPECTIVELY, 1965-1969

Model	Equation*	R^2	$\bar{Y}$	Standard Error of Estimate
Total Yield of Corn Silage				
I	$\hat{Y} = 62.6777 - 0.0653$ Sand (2) $+ 0.3036$ Silt (2) $- 0.0301$ Mg (1) $- 0.0584$ Mg (3) $- 0.3389$ Ca/Mg (1) $+ 0.1258$ AWHC $- 0.0002588$ AWHC^2 $- 4.1617$ Prec $- 0.0030$ DD $- 0.0000058$ DD^2 $+ 0.0016$ DD $\cdot$ Prec $- 0.1689$ ET Jun $+ 0.0002726$ ET Jun^2 $+ 0.0198$ ET Jul $+ 0.0351$ ET Aug $- 0.0001045$ ET Aug^2	0.741	12.85	2.68
II	$\hat{Y} = 63.8067 + 13.1119$ BD (1) $- 0.0326$ Mg (1) $+ 0.0930$ K (2) $- 0.1576$ AWHC $+ 0.0002$ AWHC^2 $- 3.6559$ Prec $- 0.0005$ DD $- 0.0000052$ DD^2 $+ 0.0014$ DD $\cdot$ Prec $- 0.1624$ ET Jun $+ 0.0002905$ ET Jun^2 $+ 0.0180$ ET Jul $+ 0.0363$ ET Aug $- 0.0001123$ ET Aug^2	0.730	12.85	2.69
Grain Content in Corn Silage (Percent)				
I	$\hat{Y} = 31.4999 + 0.0087$ Sand (2) $+ 0.1742$ Silt (2) $- 0.0081$ Mg (1) $- 0.0292$ Mg (3) $- 0.1660$ Ca/Mg (1) $+ 0.0710$ AWHC $- 0.0001394$ AWHC^2 $- 2.8587$ Prec $+ 0.0002$ DD $- 0.0000046$ DD^2 $+ 0.0011$ DD $\cdot$ Prec $- 0.0868$ ET Jun $+ 0.0001371$ ET Jun^2 $+ 0.0094$ ET Jul $+ 0.0222$ ET Aug $- 0.0000501$ ET Aug^2	0.666	5.05	1.57

TABLE XIII (continued)

Model	Equation*	R^2	$\bar{Y}$	Standard Error of Estimate
II	$\hat{Y} = 36.4194 + 7.0415\ \mathrm{BD}\ (1) - 0.0112\ \mathrm{Mg}\ (1) + 0.0443\ \mathrm{K}\ (2)$ $- 0.0675\ \mathrm{AWHC} + 0.0001127\ \mathrm{AWHC}^2 - 2.8325\ \mathrm{Prec} + 0.0006\ \mathrm{DD}$ $- 0.0000046\ \mathrm{DD}^2 + 0.0011\ \mathrm{DD} \cdot \mathrm{Prec} - 0.0786\ \mathrm{ET\ Jun}$ $+ 0.0001347\ \mathrm{ET\ Jun}^2 + 0.0081\ \mathrm{ET\ Jul} + 0.0232\ \mathrm{ET\ Aug}$ $- 0.0000522\ \mathrm{ET\ Aug}^2$	0.658	5.05	1.57
Total Yield of Grain Sorghum				
I	$\hat{Y} = -18.9921 + 0.0772\ \mathrm{Sand}\ (2) + 0.3670\ \mathrm{Silt}\ (1) - 0.0179\ \mathrm{Mg}\ (1)$ $- 0.0443\ \mathrm{Mg}\ (3) - 0.2196\ \mathrm{Ca/Mg}\ (1) + 0.0938\ \mathrm{AWHC}$ $- 0.0003477\ \mathrm{AWHC}^2 + 2.4507\ \mathrm{Prec} - 0.0367778\ \mathrm{Prec}^2$ $+ 0.00004\ \mathrm{DD} \cdot \mathrm{AWHC} - 0.0005\ \mathrm{DD} \cdot \mathrm{Prec} - 0.1115\ \mathrm{ET\ Jun}$ $+ 0.0001820\ \mathrm{ET\ Jun}^2 + 0.0254\ \mathrm{ET\ Aug} - 0.0000497\ \mathrm{ET\ Aug}^2$	0.619	10.62	2.12
II	$\hat{Y} = 22.9253 - 5.1235\ \mathrm{BD}\ (3) - 0.0191\ \mathrm{Mg}\ (1) - 0.0156\ \mathrm{Mg}\ (3)$ $+ 0.0495\ \mathrm{P}\ (1) + 0.0544\ \mathrm{K}\ (2) - 0.0746\ \mathrm{Ca/Mg}\ (1)$ $+ 0.6287\ \mathrm{Prec} - 0.0262177\ \mathrm{Prec}^2 - 0.000006\ \mathrm{DD} \cdot \mathrm{AWHC}$ $+ 0.00009\ \mathrm{DD} \cdot \mathrm{Prec} - 0.0800\ \mathrm{ET\ Jun} + 0.0001415\ \mathrm{ET\ Jun}^2$ $+ 0.0226\ \mathrm{ET\ Aug} - 0.0000450\ \mathrm{ET\ Aug}^2$	0.564	10.62	2.12
Total Yield of Forage Sorghum				
I	$\hat{Y} = 105.9381 - 1.0456\ \mathrm{Sand}\ (1) + 0.6184\ \mathrm{Sand}\ (2)$ $- 0.7970\ \mathrm{Silt}\ (1) + 0.7464\ \mathrm{Silt}\ (2) - 0.0146\ \mathrm{Mg}\ (1)$ $- 0.0542\ \mathrm{Mg}\ (3) - 0.4317\ \mathrm{Ca/Mg}\ (1) - 0.1211\ \mathrm{AWHC}$ $-0.5389\ \mathrm{Prec} - 0.0163\ \mathrm{DD} + 0.00005\ \mathrm{DD} \cdot \mathrm{AWHC} - 0.0466\ \mathrm{ET\ Jun}$ $+ 0.0047\ \mathrm{ET\ Jul} + 0.0000306\ \mathrm{ET\ Jul}^2 + 0.0159\ \mathrm{ET\ Aug}$	0.555	17.87	4.96

TABLE XIII (continued)

Model	Equation*	R^2	$\bar{Y}$	Standard Error of Estimate
II	$\hat{Y}$ = 49.5976 + 42.0708 BD (1) - 50.6352 BD (3) - 0.0563 Mg (1) + 0.0863 BS (1) + 0.0840 P (1) + 0.1872 Ca/Mg (1) + 0.0002 DD + 0.000002 DD · AWHC - 0.0003 DD · Prec - 0.0405 ET Jun - 0.0128 ET Jul + 0.0000696 ET Jul^2 + 0.0298 ET Sep - 0.0000311 ET Sep^2	0.538	17.87	5.02
Total Yield of Sudax SX-11				
I	$\hat{Y}$ = 7.9159 - 0.0983 Sand (1) - 0.4280 Silt (1) + 0.3431 Silt (2) - 0.0078 Mg (3) - 0.0224 AWHC + 0.7078 Prec - 0.0187950 $Prec^2$ + 0.0018 DD + 0.0056 ET Jun + 0.0000172 ET Jun^2 - 0.0189 ET Jul + 0.0200 ET Sep	0.537	7.27	1.95
II	$\hat{Y}$ = 6.9205 + 7.4899 BD (1) - 15.2495 BD (3) - 0.0141 Mg (1) - 0.0130 Mg (3) + 0.0252 P (1) + 0.0171 AWHC - 0.0000676 $AWHC^2$ + 1.0809 Prec - 0.0271316 $Prec^2$ + 0.0016 DD + 0.0104 ET Jun - 0.0223 ET Jul + 0.0000094 ET Jul^2 + 0.0146 ET Sep + 0.0000134 ET Sep^2	0.536	7.27	1.99
Total Yield of Gahi-1				
I	$\hat{Y}$ = -4.6994 + 0.0738 Sand (2) + 0.0757 Silt (2) - 0.0005 Mg (1) - 0.0235 AWHC + 0.8561 Prec - 0.0201 $Prec^2$ - 0.0007 DD + 0.000009 DD · AWHC - 0.0149 ET Jul + 0.0053 ET Sep + 0.0000294 ET Sep^2	0.473	7.11	1.61
II	$\hat{Y}$ = 15.5181 + 6.5981 BD (1) - 11.5802 BD (3) - 0.0109 Mg (1) - 0.0057 Mg (3) + 0.0108 P (1) - 0.0313 AWHC + 0.6017 Prec - 0.0145768 $Prec^2$ - 0.0006 DD + 0.000009 DD · AWHC - 0.0247 ET Jul + 0.0000210 ET Jul^2 + 0.0156 ET Sep	0.500	7.11	1.59

* = Values for pH, Ca, Mg, P, K, and BS were determined by Oonmuang (45).

The time-temperature summation index (called degree-days) was ineffective in explaining yield variations; however, the interaction term DD x Prec added greatly to the prediction equation. Silt content in horizon two was another effective variable in the final model. This supports the fact that soils high in silt also have high available water-holding capacities. The foregoing evidence indicates that the moisture supply accounts for much of the variability in corn silage yields. Mattice (40), working in the Corn Belt states, found rainfall and temperature to be dominant factors influencing corn yields. Runge and Odell (55) reported that precipitation and maximum daily temperatures 50 to 74 days before and 14 to 30 days after the full tassel stage explained up to 67 percent of corn yields variability from 1903 to 1957.

In Model II ET in June probably indicated the relative importance of available moisture at this stage of plant growth. The second most important term in the prediction equation was the linear ET in June term followed by precipitation, the interaction of DD x Prec, AWHC, $AWHC^2$, ET Aug^2, and DD^2. Again DD was the least important variable studied; however, the linear interaction DD x Prec ranked fourth in order of importance. Exchangeable K in horizon two and Mg in horizon one were effective in explaining the variation in corn silage yields. Bulk density values in the top soil horizon were more effective in predicting yield than degree-days.

<u>Grain Content in Corn Silage (Percent)</u>

Within the range of the data studied, the variation in grain content of corn silage was best accounted for by the precipitation terms in both Model I and II. As indicated by Model I, DD x Prec ranked next to precipitation in predicting grain yield variations. ET June occurred in third place. Other terms in order of importance were: ET $June^2$; $AWHC^2$; AWHC; DD^2; ET Aug^2; and ET Aug. Percent silt in horizon two and exchangeable Mg in horizon three were also effective in predicting variations in grain yields. Percent sand in horizon two and DD added very little to the prediction equation (Model I) for percent grain in corn silage.

In examining the yield data for grain production, other climatic factors added much to the prediction equation. In order of importance, the terms DD x Prec, ET $June^2$, ET June, AWHC, DD^2, $AWHC^2$, ET Aug^2, and ET Aug were effective in predicting grain yield response (Model II).

Total Yield of Grain Sorghum

When total yield of grain sorghum was regressed on the independent terms, partial regression coefficients indicated that the AWHC was the most effective variable in predicting yield.

In Model I, the magnitude of yield response to the climatic terms (ET June, ET $June^2$, Prec, AWHC, $Prec^2$, DD x AWHC, and DD x Prec) was obvious. Silt in horizon one accounted for much of the variability in total dry matter production. Exchangeable Mg in horizon one and horizon three provided a somewhat lower value in the prediction equation. The contribution of percent sand in horizon two to the yield prediction equation was less pronounced.

Model II illustrated the relationship between yield of grain sorghum and the climatic terms. ET $June^2$ appeared more related to total yield than any other term studied. The order of importance of other terms was: ET June; $Prec^2$; ET Aug; ET Aug^2; and Precipitation. Exchangeable K in horizon two, exchangeable Mg in horizon one and horizon three explained much of the variability in grain sorghum yields.

Heat unit summation values did not enter the equation, and it was also noted that degree-day x AWHC and degree-day x Prec contributed relatively little to the yield prediction equation. The Ca/Mg ratio in horizon one was least effective in explaining yield variations in Model II.

Total Yield of Forage Sorghum

In the forage sorghum treatments, sand content in horizon one, and percent silt in horizon one and horizon two were significant sources of variation in total dry matter production. As indicated by Model I, percent sand and silt in horizon one and percent silt in horizon two were the three most effective terms in predicting crop yield.

Although the degree-days index for the growing season was a relatively poor predictor of yield, the interaction DD x AWHC was very effective. Available water-holding capacity also appeared to be highly related to total yield of forage sorghum. Another soil variable, percent sand in horizon two, related quite well to yield. ET July was relatively ineffective in explaining variations in dry matter production.

In Model II, bulk density of horizon three, Mg in horizon one, and bulk density of horizon one were important variables in the yield prediction equation. The terms ET $July^2$, ET June and ET Sep contributed greatly to the model. The thermal index was the least important term included in the regression analysis.

Total Yield of Sudax SX-11

The amounts of silt in horizon one and horizon two were most significant of all the factors studied in explaining yield variations (Model I) in Sudax SX-11. The quadratic and linear terms of precipitation were the third and fourth most valuable terms, followed by ET Sep, ET July and AWHC.

Model II showed production as a function of 15 terms. The linear and quadratic terms of precipitation accounted for the greatest variation in total yield while the $AWHC^2$ ranked third. Other terms ranked in order of importance as to their usefulness in explaining variation in yield were ET July, ET Sep, bulk density in horizon three, AWHC, Mg in horizon one, ET June, Mg in horizon three, bulk density in horizon one, ET Sep^2, DD, ET $July^2$ and available P in horizon one.

Total Yield of Gahi-1

The linear and quadratic terms of precipitation were most useful in accounting for the variation in yield of Gahi-1. The thermal effect ranked next to last in order of importance in predicting yield; however, the interaction term DD x AWHC ranked third in explaining yield variations. The remaining terms in order of importance were: AWHC; ET July; ET Sep^2; percent silt in horizon two; percent sand in horizon two; ET Sep; DD; and exchangeable Mg in horizon one.

The data presented suggest that the growth and yield of Gahi-1 was in part a function of available moisture as it was controlled by soil moisture and temperature levels.

The prediction equation of Model II indicated that ET July, the linear and quadratic effect of precipitation, AWHC, DD x AWHC interaction, ET Sep and ET July^2 as being among the best indicators of total production. The thermal index by itself contributed very little to the yield equation. Available P in horizon one ranked last in explaining variation in total dry matter production.

<u>Summary and General Considerations</u>

Regression analyses were employed to evaluate the relative effectiveness of 35 soil terms and 16 climatic terms. Dependent variables were yield observations as measured at 82 location-treatment-years. Agronomic data for each crop were analyzed by two procedures, Model I and Model II. Model I employed 20 independent soil variables, some of which can be obtained relatively easily and require only modest scientific expertise. Twenty-five soil variables were employed by Model II, some of which were included in Model I; however, percent silt and sand, and pH appeared only in Model I. These variables were assessed and described in Model II by substituting bulk density, base saturation, available P and exchangeable K. The 16 climatic terms were included in both models. With experimentation dispersed over a wide range of conditions (physical and chemical properties of 12 soil types, variation in climate at six locations over five years, etc.), yield was characterized by two different models.

The two final models for each crop were evaluated as to their relative usefulness in estimating yield variations of each crop. Included in the final models were those independent terms which were most meaningful in the yield prediction equation. A probability level less than or equal to 0.20 was established as indicating sufficient contribution for inclusion in Model I and Model II. The order of terms in each model was based on the ranked values of the standard partial regression coefficients in prior analyses. The coefficients of total determination (R^2) for the five crops (Table XII, page 51) ranged from 0.47 to 0.74.

The coefficients of determination (R^2) of the final Model I equations were 0.74, 0.66, 0.61, 0.55, 0.53, and 0.47 for corn silage total yield, corn silage grain production, grain sorghum yield, forage sorghum yield, Sudax SX-11, and Gahi-1 total yield, respectively. R^2 values for Model II equations were 0.73, 0.65, 0.56, 0.53, 0.53, and 0.50 for corn silage total yield, corn silage grain yield, and total yield of grain sorghum, forage sorghum, Sudax SX-11 and Gahi-1, respectively. Thus, the regression analyses indicated that more variability in yield of corn silage was explained by these terms than was true for the other crops studied. Only 47 percent of the variation in dry matter yields of Gahi-1 could be accounted for by the variables included in this study. As previously mentioned, only 11 terms were retained in the final prediction model since it was determined that Gahi-1 yields were not appreciably related to the 38 deleted terms. This could be construed to indicate that Sudax SX-11 and Gahi-1 could be expected to produce high yields under a wider variety of physical and climatic conditions than the other three crops.

When crop yields were related to soil and climatic variables, percent silt, soil moisture (AWHC) and associated climatic variables generally ranked high relative to associated fertility factors in explaining variation in yield. For the crop growing seasons, yield usually was independent of the time-temperature index; however, the interaction between degree-days accumulated and precipitation or AWHC ranked high among the list of terms in explaining variability in crop yields.

All analyses presented in Table XII, page 51, indicate the negative relationship of exchangeable Mg in the yield prediction equation in contrast to the remaining soil variables. The yield prediction equation for each crop for either model resulted in a negative relation between yield and exchangeable Mg in horizon one and horizon three. High rates of N, P, and K fertilization had been applied and it was assumed that sufficient quantities of P, K, and Ca were available. Evidence that there is a close relationship between Mg and clay content was reported by Rice and Kamprath (53). From a study of five soils, they stated, "Because these soils are highly weathered, it is expected all of the Mg is associated with the clay fraction. Expressing the total Mg on a per gram of clay basis gives a much better idea of the Mg status of the soils than expressing it on a whole soil basis." In the highly weathered soils of this study, total Mg content might be expected to increase with increasing clay content in the profile. Clay content increased with depth and, at the same time, the percent base saturation decreased. Thus, using the reasoning of Rice and Kamprath, the Mg per gram of clay may actually decrease with increasing depth. Likewise, increased clay content and lower pH values give rise to higher levels of Al and Mn which could result in decreased plant growth and subsequent yields.

The predictive ability of the terms in Model I was as good as those included in Model II. The latter model had a slightly higher R^2 value than Model I only in the Gahi-1 yield analysis. As demonstrated in this study, the agronomic variables, percent sand and percent silt and pH (Model I) are to be preferred to measurements of bulk density and base saturation, available P and exchangeable K (Model II), in predicting crop yields. Furthermore, Model I is more practical, since percent sand and percent silt can be estimated rather easily in the field and soil pH can be determined rather easily in the laboratory. Model II also employed five terms more than did Model I. Therefore, Model I is preferable to Model II in explaining variation in yields of the crops studied.

CHAPTER V

SUMMARY AND CONCLUSIONS

This investigation was intended to complete the third phase of a three-part summer annual adaptation study. The first part was conducted by Oonmuang (45) who analyzed selected chemical characteristics within and among 12 soil types. These soils were common to all three parts of the study. Manning (39) studied the variation in P, K, Ca and Mg content at different stages of growth of corn and grain sorghum under a wide range of environmental conditions. The objectives of the investigation reported herein were:

1. To determine the interrelationship of soil types and environments on yield and associated characteristics of five forage crops.
2. To evaluate corn and grain sorghum dry matter yields and corresponding nutrient uptake as affected by available soil moisture, planting dates, and soil types.
3. To develop regression equations that describe summer annual forage production on some Tennessee soils.

Yield of corn silage, grain sorghum, forage sorghum, Sudax SX-11, and Gahi-1 was measured for 82 location-treatment-years. This investigation was carried out at six locations which involved two planting dates of each crop and two soil types adjacent at each location. The two soils at each location were selectively "paired" for their expected differences in soil moisture-plant relationships during a year with average rainfall and temperature. Differences between the two soils at each location were analyzed. Variations in temperatures and precipitation patterns were also evaluated for each location. Daily minimum and maximum temperatures, and precipitation data, were evaluated.

Soil type was influential in affecting yield of most forage crops in this study. Generally, the soil with the most desirable moisture characteristics in the "pair" at each of the six locations had higher crop production. Sequatchie, Huntington, Collins, Emory, Loring, and Hartsells had higher production than the soils "paired" with them: Sequoia; Dickson; Grenada; Maury; Dexter; and Tilsit, respectively. The differences in soil types were reflected by environmental stresses on dry matter production during 1965-1969. Although yield fluctuations at each of the six locations were noted among years, the yield at any one location generally remained higher for that soil having a higher moisture supplying capacity.

Total dry matter and grain production were usually higher from the early plantings than from those planted four to five weeks later. During the years studied, corn silage yields from the early plantings were increased 50, 23, 14, 28, and 17 percent at Knoxville, Martin, Spring Hill, Jackson, and Crossville, respectively. The late planting of grain sorghum in 1969 resulted in a 17 percent increase in dry matter production when compared to the early planting at Crossville. Yields of grain sorghum at Knoxville, Martin, Spring Hill, and Jackson were increased 52, 19, 18, and 21 percent by planting early. Average yields of early planted forage sorghum were 33, 40, 24, and 15 percent higher than those obtained from the late plantings at Knoxville, Martin, Spring Hill, and Jackson, respectively.

Total yields of Sudax SX-11 were higher from the early plantings than from the late plantings at all locations except Springfield. No difference in yields from the early and late planted crop were observed at Springfield. Average increases in yield from the early planted Sudax SX-11 crop were 31, 29, 26, 25, and 55 percent at Knoxville, Martin, Spring Hill, Jackson, and Crossville, respectively. Early-planted Gahi-1 produced 34, 31, 28, and 18 percent more dry matter than when planted later at Knoxville, Martin, Spring Hill, and Jackson, respectively.

On the other hand, the delay in planting usually resulted in more total dry matter produced by Sudax SX-11 and Gahi-1 after August 1. After-August-1 average yields for the late plantings of Sudax SX-11 were increased 26, 50, 42, and 14 percent when compared to the early plantings at Knoxville, Springfield, Spring Hill, and Jackson, respectively. Yield after August 1 in 1969 was 50 percent higher for the early planted Sudax SX-11 than when planted later at Crossville. Average Gahi-1 dry matter production after August 1 from the early plantings was 35, 29, 34, 29, and 40 percent higher than the late plantings at Knoxville, Springfield, Spring Hill, Jackson, and Crossville, respectively.

Even though rainfall during the 1969 growing season was considered to be favorable for high yields, irrigated corn silage plots gave an average increase of 19 percent at Knoxville and a 50 percent increase at

Jackson. The irrigated treatments of grain sorghum and forage sorghum resulted in an increase of 19 and 37 percent when compared to the non-irrigated plots at Spring Hill, respectively. Thus, maximum production of the crops grown for silage could not be sustained with naturally occurring soil moisture in that year. On the other hand, supplemental irrigation of Sudax SX-11 and Gahi-1 increased neither total yield nor yield after August 1. Thus, the two greenchopped crops were more tolerant to moisture stress than were the silage crops.

Total (seasonal) uptake of N, P, K, Ca and Mg in above-ground plant parts of corn or grain sorghum was generally no different between soils at each location when not irrigated. Only Mg uptake varied with soil type. Grain sorghum harvested from nonirrigated Emory was higher in Mg than that produced on Maury. Exchangeable Mg in the Emory soil was higher throughout the profile than it was in the Maury. Such an increase in uptake of Mg may be attributed to its increased availability to grain sorghum plants.

The observed seasonal uptake of nutrients by grain sorghum and corn under irrigated conditions was different among soil types. Uptake of Mg by grain sorghum was higher when grown on Sequatchie and Emory than when grown on Sequoia and Maury. Increased soil moisture resulted in higher K, P, and Ca uptake by corn grown on Emory than on Maury. More Ca occurred in grain sorghum forage under irrigated conditions on Emory than on Maury. A relatively high amount of these elements available to plants growing in a favorable environment may account for the higher yields and nutrient uptake by plants on the Sequatchie and Emory soils.

The uptake of N, P, K, Ca and Mg by corn and grain sorghum differed with time of planting. Where differences in uptake of certain elements existed, usually the early-planted crop had higher amounts than that crop planted later. This difference may be explained by more favorable moisture levels and temperatures during the early part of the growing season.

In the 34 experiments, the only exception to higher uptake from early-planted crops occurred at Jackson. The four-week delay in planting corn on the nonirrigated plots resulted in increased N uptake. The reason for the effect of planting date on N uptake is not known.

Irrigated corn silage planted early at Knoxville resulted in greater K, Ca and Mg uptake than that planted later. This difference may be attributed to increased dry matter production from the early planting.

Uptake of P by irrigated corn was higher from the early planting than from the later planting at Spring Hill. Uptake of P, K, and K in grain sorghum forage was higher from the early planting than the later plantings at Knoxville (irrigated), Springfield, and Jackson (irrigated).

In the multiple regression analyses, detailed soil and climatological variables were evaluated over a wide range of conditions in an attempt to explain the variations in yield of each crop. A total of 51 independent variables consisting of 35 "soil-variables" were included in the preliminary yield prediction equation for each crop. In the final analyses, two models (Model I and Model II) were employed and evaluated as to their relative usefulness in estimating variation in yield for each crop. Twenty independent soil variables and 16 climatological terms were employed in Model I. Model II included 25 "soil-variables" and 16 "climatological terms." The same climatic variables and their interactions were included in the preliminary analyses of each model. Model I differed from Model II in that certain "soil-variables" appearing in Model I were assessed and described in Model II. Soil data included in Model I were percent sand and silt and pH of horizon one, two, three; whereas, Model II employed bulk density, base saturation, and available P and exchangeable K of each horizon. Thus, the two models have different degrees of application with Model I being a "simple" model requiring fewer determinations to facilitate its use. Model II on the other hand requires more extensive data.

A probability level of less than or equal to 0.20 was established as indicating sufficient contribution for inclusion in Model I and Model II. Whenever the quadratic term was included, the linear term was always included. Ordering of independent terms in the combined analyses was based on the ranked values of the standard partial regression coefficients of significant terms.

The coefficient of total determination (R^2) for the five crops ranged from 0.47 for Gahi-1 to 0.74 for corn silage. When Model II was employed, the R^2 ranged from 0.50 for Gahi-1 to 0.73 for corn silage. Approximately three-fourths of the variation in corn silage yields in these experiments was accounted for by the 16 terms kept. Less than half the variation in Gahi-1 yield was accounted for by the terms studied. This indicates that Gahi-1 yields are influenced less by variations in meteorological and soil conditions than the four other crops studied.

In this study, Model I was preferable to Model II because of its general consistency in accounting for variation in crop yields. Certain "soil-variables" (percent sand, percent silt, and pH) in Model I are more easily measured than those included in Model II (bulk density, base saturation, available P and exchangeable K). Model I also employed fewer soil variables than did Model II.

From the evidence presented in this study, it can be concluded that the moisture supply generally accounts for much of the variability in each crop yield.

The negative relationship of exchangeable Mg in the final prediction equations when compared to the other soil variables was quite noticeable in each analysis. In each multiple regression analysis, exchangeable Mg in horizon one and/or horizon two accounted for much of the variation in yield. Some evidence exists supporting the theory that total Mg is associated with clay content in highly weathered soils. The yield-magnesium relationship may be a secondary effect to increased clay content with increasing depths and the additional effects produced by higher clay content and lower pH value may account for the reduced plant growth.

Within the range of data studied, yield was usually independent of the linear effects of the time-temperature index; however, the interactions between degree-days accumulated during the growing season and available water-holding capacity, and accumulated degree-days and precipitation were generally found to be effective in explaining yield variations.

LITERATURE CITED

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APPENDIX

TABLE XIV

AVERAGE YIELDS OF CORN SILAGE, GRAIN SORGHUM AND FORAGE SORGHUM, AND PERCENT GRAIN FROM PLANTS SEEDED ON TWO DATES AT SIX LOCATIONS INVOLVING 12 DIFFERENT SOIL TYPES, 1965-1969

Location	Crop	Soil	Planting Date	Yield	Year 1969	1968	1967	1966	1965	Mean
Knoxville	Corn silage	Sequoia †‡		Total*	8.48	4.94	8.59	6.89	10.04	7.79 **
				Percent grain	31.20	23.90	40.90	40.40	39.20	36.10 ††
		Sequatchie		Total	12.22	11.46	10.00	10.32	14.16	11.63 **
				Percent grain	44.40	38.20	43.40	46.50	39.80	42.30 ††
			Early §¶	Total	13.59	10.22	11.11	8.43	14.99	11.67
				Percent grain	38.80	39.00	44.50	43.50	45.90	42.40
			Late	Total	7.11	6.18	7.48	8.78	9.22	7.75
				Percent grain	39.40	25.60	39.00	44.50	29.10	35.80
Springfield	Corn silage	Dickson †‡		Total	18.39	12.78	18.64	. .	. .	16.60 **
				Percent grain	20.80	22.60	39.00	. .	. .	28.10 ††
		Huntington		Total	26.07	23.59	19.37	. .	. .	23.01 **
				Percent grain	44.30	39.90	47.10	. .	. .	43.60 ††
			Early ¶	Total	21.92	19.63	20.10	. .	. .	20.55
				Percent grain	36.90	32.50	47.00	. .	. .	38.70
			Late	Total	22.54	16.74	17.91	. .	. .	19.06
				Percent grain	32.30	35.50	39.00	. .	. .	35.30
Martin	Corn silage	Grenada		Total	13.87	12.84	17.99	. .	. .	14.90 **
				Percent grain	39.50	35.90	43.70	. .	. .	40.20 ††
		Collins		Total	15.79	13.95	14.67	. .	. .	14.80 **
				Percent grain	32.00	34.30	43.20	. .	. .	40.80 ††
			Early §¶	Total	14.91	15.80	18.46	. .	. .	16.39
				Percent grain	44.30	40.50	44.50	. .	. .	43.20
			Late	Total	14.75	10.99	14.20	. .	. .	13.31
				Percent grain	39.90	27.20	42.20	. .	. .	37.20

TABLE XIV (continued)

Location	Crop	Soil	Planting Date	Yield	Year 1969	1968	1967	1966	1965	Mean
Spring Hill	Corn	Maury		Total	9.74	7.24	12.02	. .	. .	9.67
	silage	†‡		Percent grain	26.80	22.90	49.70	. .	. .	35.30 ††
		Emory		Total	14.57	13.75	12.83	. .	. .	13.71
				Percent grain	45.30	42.20	44.10	. .	. .	43.90 ††
			Early	Total	12.57	10.95	13.91	. .	. .	12.48
			§	Percent grain	37.00	32.70	50.80	. .	. .	40.80
			Late	Total	11.73	10.04	10.94	. .	. .	10.91
				Percent grain	38.90	38.60	41.70	. .	. .	39.70
Jackson	Corn	Dexter		Total	8.34	7.77	10.97	. .	. .	9.03 **
	silage	†		Percent grain	38.10	27.60	42.60	. .	. .	36.90 ††
		Loring		Total	9.35	9.39	11.67	. .	. .	10.14 **
				Percent grain	39.80	39.10	41.80	. .	. .	37.90 ††
			Early	Total	7.91	11.35	13.02	. .	. .	10.76
			§	Percent grain	26.40	34.70	43.30	. .	. .	36.10
			Late	Total	9.78	5.82	9.63	. .	. .	8.41
				Percent grain	49.10	19.40	40.80	. .	. .	39.10
Crossville	Corn	Tilsit		Total	15.62	. .	. .	. .	. .	. .
	silage	†‡		Percent grain	40.50	. .	. .	. .	. .	. .
		Hartsells		Total	13.12	. .	. .	. .	. .	. .
				Percent grain	34.50	. .	. .	. .	. .	. .
			Early	Total	15.51	. .	. .	. .	. .	. .
			§¶	Percent grain	39.40	. .	. .	. .	. .	. .
			Late	Total	13.23	. .	. .	. .	. .	. .
				Percent grain	34.30	. .	. .	. .	. .	. .
General Mean	Corn silage	All soils		Total	13.80	11.77	8.60	12.10	. . .	. .
				Percent grain	36.40	32.70	43.50	39.50	. . .	. .

TABLE XIV (continued)

Location	Crop	Soil	Planting Date	Yield	Year 1969	1968	1967	1966	1965	Mean
			Early	Total	14.40	13.59	8.43	14.99	. .	. .
				Percent grain	37.10	33.90	43.50	45.90	. .	. .
			Late	Total	13.19	9.95	8.78	9.22	. .	. .
				Percent grain	41.00	29.30	44.50	29.10	. .	. .
Knoxville	Grain sorghum	Sequoia †		Total	9.95	5.41	6.07	4.91	7.70	6.81 **
				Percent grain	18.30	19.80	18.90	30.80	16.00	19.90 ††
		Sequatchie		Total	10.90	9.76	6.24	7.98	11.64	9.30 **
				Percent grain	17.00	14.30	13.00	29.10	16.70	17.90 ††
			Early §	Total	12.51	9.91	7.19	7.86	11.13	9.72
				Percent grain	12.60	15.60	13.60	29.40	16.40	16.90
			Late	Total	8.34	5.25	5.13	5.04	8.20	6.39
				Percent grain	25.20	17.60	19.20	30.20	16.50	21.50
Springfield	Grain sorghum	Dickson †‡		Total	11.56	10.89	13.26	. .	. .	11.90
				Percent grain	20.70	23.40	17.60	. .	. .	20.40 ††
		Huntington		Total	15.02	13.46	12.80	. .	. .	13.76
				Percent grain	27.90	21.00	19.30	. .	. .	23.00 ††
			Early ¶	Total	13.48	12.50	13.10	. .	. .	13.03
				Percent grain	18.50	24.60	16.40	. .	. .	19.70
			Late	Total	13.11	11.86	12.96	. .	. .	12.64
				Percent grain	31.20	19.40	20.40	. .	. .	23.80
Martin	Grain sorghum	Grenada ‡		Total	14.19	12.69	12.78	. .	. .	13.22 **
				Percent grain	20.00	22.60	16.50	. .	. .	19.70 ††
		Collins		Total	16.58	14.08	11.07	. .	. .	13.91 **
				Percent grain	18.00	18.30	14.40	. .	. .	17.10 ††
			Early §¶	Total	16.32	14.45	13.51	. .	. .	14.76
				Percent grain	15.00	19.90	13.10	. .	. .	16.00
			Late	Total	14.46	12.32	10.34	. .	. .	12.37
				Percent grain	23.30	21.00	18.80	. .	. .	21.30

TABLE XIV (continued)

Location	Crop	Soil	Planting Date	Yield	Year 1969	1968	1967	1966	1965	Mean
Spring Hill	Grain sorghum	Maury †‡		Total	9.28	6.83	7.65	. .	. .	7.92 **
				Percent grain	21.40	21.50	16.40	. .	. .	19.80 ††
		Emory		Total	12.43	11.04	8.71	. .	. .	10.73 **
				Percent grain	17.30	16.80	17.70	. .	. .	17.20 ††
			Early §¶	Total	11.57	10.11	8.65	. .	. .	10.11
				Percent grain	20.40	23.00	14.00	. .	. .	19.40
			Late	Total	10.14	7.76	7.70	. .	. .	8.54
				Percent grain	17.50	12.80	20.60	. .	. .	17.00
Jackson	Grain sorghum	Dexter		Total	10.97	7.46	8.30	. .	. .	8.91 **
				Percent grain	26.20	28.60	26.80	. .	. .	27.10 ††
		Loring		Total	11.37	7.76	8.78	. .	. .	9.30 **
				Percent grain	29.80	28.30	26.30	. .	. .	28.30 ††
			Early §	Total	12.35	8.11	9.48	. .	. .	9.98
				Percent grain	21.80	28.00	25.20	. .	. .	24.60
			Late	Total	9.99	7.11	7.60	. .	. .	8.23
				Percent grain	35.80	29.00	28.20	. .	. .	31.50
Crossville	Grain sorghum	Tilsit		Total	12.42	. .	. .	. .	. .	. .
				Percent grain	18.30	. .	. .	. .	. .	. .
		Hartsells		Total	12.54	. .	. .	. .	. .	. .
				Percent grain	16.00	. .	. .	. .	. .	. .
			Early §¶	Total	11.51	. .	. .	. .	. .	. .
				Percent grain	12.80	. .	. .	. .	. .	. .
			Late	Total	13.45	. .	. .	. .	. .	. .
				Percent grain	22.40	. .	. .	. .	. .	. .
General Mean	Grain sorghum	All soils		Total	12.27	9.94	9.56	6.45	9.67	. .
				Percent grain	20.90	21.50	18.70	30.00	16.40	. .

TABLE XIV (continued)

Location	Crop	Soil	Planting Date	Yield	Year 1969	1968	1967	1966	1965	Mean
			Early	Total	12.96	11.02	10.39	7.86	11.13	. .
				Percent grain	16.90	22.20	16.50	29.40	16.40	. .
			Late	Total	11.58	8.86	8.74	5.04	8.20	. .
				Percent grain	25.90	20.00	21.40	30.20	16.50	. .
Knoxville	Forage sorghum	Sequoia †		Total	15.33	9.69	9.14	7.55	11.42	10.62 **
				Percent grain	24.90	20.50	21.90	16.50	23.20	21.90 ††
		Sequatchie		Total	18.03	15.28	11.04	10.29	20.55	15.04 **
				Percent grain	24.00	15.30	9.90	12.40	11.10	14.50 ††
			Early §	Total	22.74	13.85	9.84	5.12	21.71	14.65
				Percent grain	18.60	15.90	11.90	13.10	13.10	15.20
			Late	Total	10.62	11.11	10.34	12.71	10.25	11.01
				Percent grain	22.70	19.10	18.50	14.50	20.20	18.80
Springfield	Forage sorghum	Dickson †‡		Total	18.92	20.89	29.51	. .	. .	23.11 **
				Percent grain	17.30	16.90	11.40	. .	. .	15.50 ††
		Huntington		Total	29.03	25.39	28.09	. .	. .	27.50 **
				Percent grain	13.00	16.80	11.90	. .	. .	21.20 ††
			Early ¶	Total	27.49	23.02	28.80	. .	. .	26.44
				Percent grain	13.00	18.50	11.40	. .	. .	14.00
			Late	Total	20.46	23.25	28.80	. .	. .	24.17
				Percent grain	46.80	15.30	12.00	. .	. .	22.80
Martin	Forage sorghum	Grenada †		Total	24.90	16.20	19.49	. .	. .	20.20 **
				Percent grain	18.00	23.70	12.60	. .	. .	17.80 ††
		Collins		Total	27.44	25.54	18.27	. .	. .	23.75 **
				Percent grain	19.30	12.50	13.70	. .	. .	15.40 ††

TABLE XIV (continued)

Location	Crop	Soil	Planting Date	Yield	Year 1969	1968	1967	1966	1965	Mean
			Early	Total	31.32	24.38	21.24	. .	. .	25.65
			§	Percent grain	17.40	14.10	11.80	. .	. .	14.80
			Late	Total	21.03	17.36	16.52	. .	. .	18.30
				Percent grain	20.60	20.70	14.90	. .	. .	18.90
Spring Hill	Forage	Maury		Total	14.22	11.81	16.25	. .	. .	14.09
	sorghum	†‡		Percent grain	18.10	16.60	10.60	. .	. .	14.80 ††
		Emory		Total	21.92	19.12	16.63	. .	. .	19.22
				Percent grain	14.50	12.70	11.50	. .	. .	13.00 ††
			Early	Total	20.31	16.66	18.34	. .	. .	18.44
			§¶	Percent grain	14.70	16.10	11.20	. .	. .	14.00
			Late	Total	15.83	14.27	14.54	. .	. .	14.88
				Percent grain	17.40	12.00	10.90	. .	. .	13.60
Jackson	Forage	Dexter		Total	18.23	11.20	10.82	. .	. .	13.42 **
	sorghum			Percent grain	26.70	23.10	15.50	. .	. .	22.70 ††
		Loring		Total	17.90	14.55	12.28	. .	. .	14.91 **
				Percent grain	32.60	17.80	13.60	. .	. .	22.50 ††
			Early	Total	18.35	14.78	11.54	. .	. .	14.89
			§¶	Percent grain	34.30	19.50	14.00	. .	. .	24.10
			Late	Total	17.77	10.98	11.55	. .	. .	13.43
				Percent grain	24.80	20.90	15.00	. .	. .	20.90
Crossville	Forage	Tilsit		Total	14.19	. .	. .	. .	. .	. .
	sorghum			Percent grain	18.30	. .	. .	. .	. .	. .
		Hartsells		Total	15.43	. .	. .	. .	. .	. .
				Percent grain	16.00	. .	. .	. .	. .	. .

TABLE XIV (continued)

Location	Crop	Soil	Planting Date	Yield	Year 1969	1968	1967	1966	1965	Mean
			Early	Total	14.47	. .	. .	. .	. .	. .
				Percent grain	16.90	. .	. .	. .	. .	. .
			Late	Total	15.15	. .	. .	. .	. .	. .
				Percent grain	19.20	. .	. .	. .	. .	. .
General Mean	Forage sorghum	All soils		Total	19.63	16.97	15.53	8.92	15.98	. .
				Percent grain	22.20	17.60	13.30	14.50	17.20	. .
			Early	Total	22.45	18.54	17.95	5.12	21.71	. .
				Percent grain	19.20	16.80	12.10	13.10	13.10	. .
			Late	Total	16.81	15.39	16.35	12.71	10.25	. .
				Percent grain	25.30	17.60	14.30	14.50	20.20	. .

* = Total yield in metric tons per hectare.

† = Mean difference for total yield between two soils at a location, $P < .05$.

‡ = Mean difference for percent grain between two soils at a location, $P < .05$.

§ = Mean difference for total yield between plantings at a location, $P < .05$.

¶ = Mean difference for percent grain between plantings at a location, $P < .05$.

** = Difference in total yield from a soil among years, $P < .05$.

†† = Difference in percent grain from a soil among years, $P < .05$.

TABLE XV

ANALYSES OF VARIANCE FOR THE EFFECTS OF YEARS, SOIL TYPES, PLANTING DATES, AND THEIR INTERACTIONS, ON THE TOTAL YIELDS OF CORN SILAGE, GRAIN SORGHUM AND FORAGE SORGHUM AND THE GRAIN PERCENTAGES AT SIX LOCATIONS, 1965-1969

Source of Variation	d.f.	Mean Squares Total Yield	Mean Squares Grain percent	Source of Variation	d.f.	Mean Squares Total Yield	Mean Squares Grain percent
			Corn Silage				
Knoxville				Springfield			
Year (Y)	4	7.81*	1.64*	Year (Y)	2	14.58*	3.66*
Soil type (S)	1	58.76*	17.62*	Soil type (S)	1	97.98*	68.82*
Planting (P)	1	61.06*	18.79*	Planting (P)	1	5.26	3.61*
Y X S	4	2.66*	0.69	Y X S	2	21.15*	7.57*
Y X P	4	5.63*	2.02*	Y X P	2	2.75	0.93
S X P	1	8.10*	1.04	S X P	1	6.11	1.86
Residual	64	0.81	0.32	Residual	38	1.60	0.56
Martin				Spring Hill			
Year (Y)	2	6.85*	4.72*	Year (Y)	2	3.38	3.50*
Soil type (S)	1	0.02	0.01	Soil type (S)	1	35.19*	14.57*
Planting (P)	1	22.63*	10.73*	Planting (P)	1	5.30*	1.25
Y X S	2	6.33*	1.88*	Y X S	2	6.77*	4.93*
Y X P	2	5.16*	1.44*	Y X P	2	1.11	1.80*
S X P	1	0.82	1.83*	S X P	1	0.72	0.19
Residual	38	0.65	0.25	Residual	34	1.16	0.53
Jackson				Crossville			
Year (Y)	2	7.27*	4.08*	Soil type (S)	1	4.98*	3.24*
Soil type (S)	1	2.93*	0.62	Planting (P)	1	4.12*	1.97*
Planting (P)	1	13.24*	0.86	S X P	1	0.20	0.06
Y X S	2	0.17	0.07	Residual	12	0.67	0.29
Y X P	2	11.54*	6.80*				
S X P	1	0.61	0.09				
Residual	38	0.51	0.23				
			Grain Sorghum				
Knoxville				Springfield			
Year (Y)	4	11.65*	0.51*	Year (Y)	2	1.08	0.66*
Soil type (S)	1	24.79*	0.37	Soil type (S)	1	8.23*	1.28*
Planting (P)	1	44.08*	0.29	Planting (P)	1	0.35	0.47*
Y X S	4	2.73*	0.18	Y X S	2	3.35*	0.67*
Y X P	4	0.90	0.22	Y X P	2	0.05	1.13*
S X P	1	1.65*	0.00	S X P	1	1.23	1.04*
Residual	64	0.49	0.11	Residual	38	0.42	0.05

TABLE XV (continued)

Source of Variation	d.f.	Mean Squares Total Yield	Mean Squares Grain	Source of Variation	d.f.	Mean Squares Total Yield	Mean Squares Grain
			percent				percent
Martin				Spring Hill			
Year (Y)	2	9.62*	1.01*	Year (Y)	2	5.04*	0.31*
Soil type (S)	1	1.13	0.12*	Soil type (S)	1	16.91*	0.16*
Planting (P)	1	13.63*	0.17*	Planting (P)	1	5.34*	0.56*
Y X S	2	3.63*	0.09*	Y X S	2	2.03*	0.01
Y X P	2	0.38	0.29*	Y X P	2	0.40	0.58*
S X P	1	4.81*	0.01	S X P	1	0.12	0.01
Residual	38	0.38	0.02	Residual	34	0.51	0.01
Jackson				Crossville			
Year (Y)	2	10.88*	0.89*	Soil type (S)	1	0.01	0.17
Soil type (S)	1	0.37	0.12	Planting (P)	1	2.99*	1.88*
Planting (P)	1	7.28*	0.05	S X P	1	1.06	0.04
Y X S	2	0.01	0.05	Residual	12	0.43	0.05
Y X P	2	0.38	0.33*				
S X P	1	2.05*	0.08				
Residual	38	0.20	0.03				
			Forage Sorghum				
Knoxville				Springfield			
Year (Y)	4	35.62*	1.92*	Year (Y)	2	29.73*	9.46*
Soil type (S)	1	73.91*	0.09	Soil type (S)	1	46.11*	14.26*
Planting (P)	1	50.67*	0.09	Planting (P)	1	12.28	7.87*
Y X S	4	6.68*	0.19*	Y X S	2	26.39*	10.40*
Y X P	4	52.34*	1.06*	Y X P	2	13.51*	10.55*
S X P	1	2.17	0.09	S X P	1	51.11*	14.14*
Residual	61	1.72	0.04	Residual	38	3.11	0.52
Martin				Spring Hill			
Year (Y)	2	45.25*	4.61*	Year (Y)	2	4.65	0.77*
Soil type (S)	1	30.17*	0.01	Soil type (S)	1	56.56*	0.38*
Planting (P)	1	128.92*	0.26	Planting (P)	1	27.25*	0.67*
Y X S	2	22.82*	0.43	Y X S	2	12.79*	0.03
Y X P	2	6.22*	0.37	Y X P	2	0.81	0.10*
S X P	1	8.97*	0.38	S X P	1	5.64	0.10*
Residual	38	1.24	0.21	Residual	34	1.66	0.02
Jackson				Crossville			
Year (Y)	2	37.71*	11.68*	Soil type (S)	1	1.22	0.01
Soil type (S)	1	5.31*	0.24*	Planting (P)	1	0.36	0.17*
Planting (P)	1	5.08*	1.46*	S X P	1	0.46	0.00
Y X S	2	2.70*	0.24*	Residual	12	0.49	0.02
Y X P	2	3.35*	0.81*				
S X P	1	0.03	0.82*				
Residual	38	0.48	0.05				

* P < .05.

TABLE XVI

ANALYSES OF VARIANCE FOR THE EFFECTS OF SOIL TYPES, PLANTING DATES, IRRIGATION AND THEIR INTERACTIONS ON THE TOTAL YIELDS OF CORN SILAGE, GRAIN SORGHUM, AND FORAGE SORGHUM AND THE GRAIN PERCENTAGES AT THREE LOCATIONS, 1969

Source of Variation	d.f.	Mean Squares Total Yield	Mean Squares Grain percent	Source of Variation	d.f.	Mean Squares Total Yield	Mean Squares Grain percent
Corn Silage				Grain Sorghum			
Knoxville				Knoxville			
Soil type (S)	1	2.34	1.70	Soil type (S)	1	0.87	0.09
Planting (P)	1	57.20*	6.92*	Planting (P)	1	14.36*	0.50
Irrigation (I)	1	5.96*	1.64	Irrigation (I)	1	1.92	0.01
S X P	1	25.96*	7.58*	S X P	1	1.24	2.07*
S X I	1	10.19*	4.87*	S X I	1	0.07	0.12
P X I	1	0.38	0.23	P X I	1	2.15	0.00
Residual	25	1.23	0.57	Residual	25	0.58	0.13
Spring Hill				Spring Hill			
Soil type (S)	1	18.62*	9.35*	Soil type (S)	1	8.30*	0.04*
Planting (P)	1	0.12	0.10	Planting (P)	1	0.45	0.19*
Irrigation (I)	1	5.20	1.82	Irrigation (I)	1	5.26*	0.00
S X P	1	1.22	0.02	S X P	1	0.38	0.00
S X I	1	0.93	1.71	S X I	1	0.31	0.00
P X I	1	0.33	0.15	P X I	1	4.98*	0.04*
Residual	17	1.43	0.52	Residual	17	0.50	0.01
Jackson				Jackson			
Planting (P)	1	3.03*	3.10*	Planting (P)	1	17.97*	0.44*
Irrigation (I)	1	13.60*	6.31*	Irrigation (I)	1	0.00	0.00
P X I	1	0.00	0.15	P X I	1	0.16	0.00
Residual	10	0.32	0.12	Residual	10	0.94	0.09

TABLE XVI (continued)

Source Variation	d.f.	Mean Squares Total Yield	Mean Squares Grain	Source of Variation	d.f.	Mean Squares Total Yield	Mean Squares Grain
			percent				percent
Forage Sorghum							
Knoxville							
Soil type (S)	1	10.48	0.01				
Planting (P)	1	165.90*	4.61*				
Irrigation (I)	1	11.00	0.21				
S X P	1	7.24	0.00				
S X I	1	0.01	0.01				
P X I	1	1.04	0.00				
Residual	21	3.18	0.05				
Spring Hill							
Soil type (S)	1	19.62*	0.35*				
Planting (P)	1	18.75*	0.01				
Irrigation (I)	1	52.22*	0.34*				
S X P	1	6.61	0.00				
S X I	1	15.89*	0.01				
P X I	1	0.32	0.04				
Residual	17	3.23	0.06				
Jackson							
Planting (P)	1	3.98	0.14*				
Irrigation (I)	1	0.09	0.09*				
P X I	1	0.28	0.04				
Residual	12	0.91	0.02				

* $P < .05$.

TABLE XVII

ANALYSES OF VARIANCE FOR THE EFFECTS OF SOIL TYPES, PLANTING DATES AND THEIR INTERACTIONS ON THE YIELDS OF CORN FOR GRAIN AT SIX LOCATIONS, 1969

Source of Variation	d.f.	Mean Squares Total Yield	Source of Variation	d.f.	Mean Squares Total Yield
Knoxville			Springfield		
Soil type (S)	1	771.45	Soil type (S)	1	65984.73*
Planting (P)	1	8607.20*	Planting (P)	1	2557.83*
S X P	1	5741.86*	S X P	1	565.25
Residual	12	747.92	Residual	12	496.02
Martin			Spring Hill		
Soil type (S)	1	9082.10*	Soil type (S)	1	9274.09*
Planting (P)	1	5076.56	Planting (P)	1	509.60
S X P	1	368.64	S X P	1	1188.03
Residual	12	1259.92	Residual	8	1326.88
Jackson			Crossville		
Soil type (S)	1	375.39	Soil type (S)	1	58.91
Planting (P)	1	215.36	Planting (P)	1	133.98
S X P	1	895.50	S X P	1	26.27
Residual	12	452.18	Residual	12	355.85

*$P < .05$.

TABLE XVIII

AVERAGE YIELDS OF SUDAX SX-11 AND GAHI-1, AND PERCENT YIELD PRODUCED AFTER AUGUST 1 FROM PLANTS SEEDED ON TWO DATES AT SIX LOCATIONS INVOLVING 12 DIFFERENT SOIL TYPES, 1965-1969

Location and Year	Sudax SX-11								Gahi-1							
	Soil				Planting Date				Soil				Planting Date			
	Total Yield	After Aug. 1	Total Yield	After Aug. 1	Total Yield	After Aug. 1	Total Yield	After Aug. 1	Total Yield	After Aug. 1	Total Yield	After Aug. 1	Total Yield	After Aug. 1	Total Yield	After Aug. 1
	t/ha	percent	t/ha	percent	t/ha	percent	t/ha	percent	t/ha	percent	t/ha	percent	t/ha	percent	t/ha	percent
Knoxville	Sequoia		Sequatchie		Early		Late		Sequoia		Sequatchie		Early		Late	
1969	6.32	56‡	6.07	52	6.77	43¶	5.62	67	6.56	56‡	6.39	55	6.56	41¶	6.39	70
1968	3.67	68	6.01	55	5.05	37**	4.63	86	5.03	69	4.64	51	5.25	37**	4.42	88
1967	5.10	47§	4.97	72	6.00	51	4.08	72	5.16	51	6.23	58	6.93	41	4.46	76
1966	4.72	79	7.39	75	7.75	58	6.61	84	5.86	89	6.97	67	7.18	59	5.65	84
1965	5.33	52	6.26	50	7.05	45	4.55	60	5.91	60	7.58	42	8.33	38	5.16	68
Mean*†	5.03	62	6.14	64	6.52	49	5.10	62	5.70	68	6.36	56	6.85	43	5.21	77
Spring-field	Dickson		Huntington		Early		Late		Dickson		Huntington		Early		Late	
1969	7.22	45‡	7.29	46	7.12	34**	7.40	56	7.48	49‡	8.02	54	8.25	40**	7.25	65
1968	8.01	42	5.67	47	7.41	33	6.27	57	7.30	53	8.56	46	7.67	42	8.19	56
1967	6.59	44§	4.79	33	5.60	35	5.78	43	5.63	37	5.81	37	5.78	39	5.66	35
Mean*†	7.27	43	5.92	43	6.71	34	6.48	53	6.80	47	7.46	46	7.23	40	7.04	53
Martin	Grenada		Collins		Early		Late		Grenada		Collins		Early		Late	
1969	7.87	36‡	11.59	40	11.02	36¶	8.45	41	9.62	50§	9.06	36	11.38	44¶	7.30	42
1968	7.38	46	9.06	43	9.22	39	7.22	51	8.07	41	8.08	54	8.09	46	8.06	48
1967	5.58	49§	5.25	49	6.13	38	4.71	62	6.70	53	6.03	47	7.54	37	5.19	69
Mean*†	6.95	43	8.63	43	8.79	38	6.79	49	8.13	48	7.72	45	9.00	43	6.85	51
Spring Hill	Maury		Emory		Early		Late		Maury		Emory		Early		Late	
1969	9.40	63‡	9.98	53	10.18	49¶	9.21	67	9.22	62	8.78	54	10.14	46¶	7.86	74
1968	6.04	59	7.32	51	8.03	41**	5.33	74	5.49	66	6.55	60	6.70	45**	5.34	84
1967	6.37	71	6.83	62	7.42	40	5.77	62	5.33	77	5.74	74	6.24	57	4.83	81
Mean*†	7.27	64	8.05	55	8.54	44	6.77	68	6.68	67	7.02	61	7.69	49	6.01	80

TABLE XVIII (continued)

Location and Year	Sudax SX-11								Gahi-1							
	Soil				Planting Date				Soil				Planting Date			
	Total Yield	After Aug. 1	Total Yield	After Aug. 1	Total Yield	After Aug. 1	Total Yield	After Aug. 1	Total Yield	After Aug. 1	Total Yield	After Aug. 1	Total Yield	After Aug. 1	Total Yield	After Aug. 1
	t/ha	percent	t/ha	percent	t/ha	percent	t/ha	percent	t/ha	percent	t/ha	percent	t/ha	percent	t/ha	percent
Jackson	Dexter		Loring		Early		Late		Dexter		Loring		Early		Late	
1969	6.41	54‡	7.29	46	7.08	41¶	6.63	59	6.91	44‡	6.92	41	7.48	36¶	6.35	50
1968	5.00	52	5.83	46	5.73	42**	5.10	56	5.19	52	5.98	49	5.97	40**	5.20	62
1967	4.82	46	6.11	45	6.88	38	4.05	56	4.85	61	5.50	54	5.49	45	4.85	70
Mean*†	5.41	51	6.41	46	6.56	41	5.26	57	5.65	51	6.13	47	6.31	40	5.47	60
Cross-ville	Tilsit		Hartsells		Early		Late		Tilsit		Hartsells		Early		Late	
1969	11.39	36‡	9.50	38	12.71	36¶**	8.18	38	6.76	27§	7.90	37	7.05	28**	7.61	37
General Mean	7.22	50	7.44	48	8.31	40	6.43	55	6.62	51	7.10	49	7.36	41	6.37	60

* = Difference among years in total production of both crops grown on the two soils and both plantings at a given location, P < .05.

† = Difference among years in production after August 1 of both crops grown on the two soils and both plantings at a given location, P < .05.

‡ = Difference between soils among years in total production of both plantings within a location, P < .05.

§ = Difference between the two soils among years in production after August 1 of both plantings within a location, P < .05.

¶ = Difference between early and late seedings among years in total yield when grown on both soils at a location, P < .05.

** = Difference between early and late seedings among years in production after August 1 when grown on both soils at a location, P < .05.

TABLE XIX

ANALYSES OF VARIANCE FOR THE EFFECTS OF YEARS, SOIL TYPES, PLANTING DATES AND THEIR INTERACTIONS ON THE TOTAL YIELDS OF SUDAX SX-11 AND GAHI-1, AND PERCENTAGES OF YIELD PRODUCED AFTER AUGUST 1 AT EACH LOCATION, 1965-1969

Source of Variation	d.f.	Mean Squares Total Yield	Mean Squares Yield After Aug. 1	Source of Variation	d.f.	Mean Squares Total Yield	Mean Squares Yield After Aug. 1
		Sudax SX-11					
Knoxville				Springfield			
Year (Y)	4	35.00*	28.75*	Year (Y)	2	2.10*	0.96*
Soil type (S)	1	16.04*	7.44*	Soil type (S)	1	4.38*	0.93*
Planting (P)	1	13.99*	4.18*	Planting (P)	1	0.12	3.06*
Y X S	4	7.43*	3.41*	Y X S	2	1.27*	0.42
Y X P	4	1.06	1.47*	Y X P	2	0.50	0.29
S X P	1	0.45	0.02	S X P	1	0.11	0.07
Residual	64	0.47	0.20	Residual	38	0.33	0.15
Martin				Spring Hill			
Year (Y)	2	15.26*	1.18*	Year (Y)	2	8.12*	2.66*
Soil type (S)	1	6.81*	1.24*	Soil type (S)	1	1.29*	0.16
Planting (P)	1	9.55*	0.01	Planting (P)	1	6.77*	5.26*
Y X S	2	3.27*	0.81*	Y X S	2	0.16	0.13
Y X P	2	0.26	0.23	Y X P	2	0.54	0.98*
S X P	1	0.06	0.27	S X P	1	0.05	0.11
Residual	38	0.20	0.12	Residual	34	0.28	0.09
Jackson				Crossville			
Year (Y)	2	2.20*	0.84*	Soil type (S)	1	2.83*	0.16
Soil type (S)	1	2.43*	0.08	Planting (P)	1	16.36*	1.88*
Planting (P)	1	4.11*	0.32*	S X P	1	0.00	0.05
Y X S	2	0.05	0.08	Residual	12	0.38	0.17
Y X P	2	1.41*	0.36*				
S X P	1	0.02	0.00				
Residual	39	0.33	0.07				
		Gahi-1					
Knoxville				Springfield			
Year (Y)	4	25.23*	22.36*	Year (Y)	2	4.80*	3.54*
Soil type (S)	1	4.63*	0.09	Soil type (S)	1	1.04*	0.14
Planting (P)	1	16.56*	6.63*	Planting (P)	1	0.09	1.67*
Y X S	4	1.78*	0.45	Y X S	2	0.24	0.08
Y X P	4	1.76*	0.50	Y X P	2	0.47	0.69*
S X P	1	4.40*	0.54	S X P	1	0.19	0.00
Residual	61	0.40	0.16	Residual	38	0.21	0.09

TABLE XIX (continued)

Source of Variation	d.f.	Mean Squares: Total Yield	Mean Squares: Yield After Aug. 1	Source of Variation	d.f.	Mean Squares: Total Yield	Mean Squares: Yield After Aug. 1
Martin				Spring Hill			
Year (Y)	2	7.10*	0.63*	Year (Y)	2	9.06*	1.57*
Soil type (S)	1	0.40	0.42*	Soil type (S)	1	0.25	0.06
Planting (P)	1	11.05*	0.30	Planting (P)	1	5.91*	3.37*
Y X S	2	0.11	1.36*	Y X S	2	0.38	0.33*
Y X P	2	3.29*	1.71*	Y X P	2	0.17	0.03
S X P	1	0.64	0.16	S X P	1	0.06	0.10
Residual	38	0.17	0.08	Residual	33	0.23	0.08
Jackson				Crossville			
Year (Y)	2	2.64*	0.03	Soil type (S)	1	1.04	0.97*
Soil type (S)	1	0.55*	0.00	Planting (P)	1	0.25	0.51*
Planting (P)	1	1.68*	1.29*	S X P	1	0.07	0.32*
Y X S	2	0.14	0.04	Residual	12	0.24	0.05
Y X P	2	0.05	0.05				
S X P	1	0.06	0.01				
Residual	38	0.09	0.04				

* P < .05.

TABLE XX

ANALYSES OF VARIANCE FOR THE EFFECTS OF SOIL TYPES, PLANTING DATES, IRRIGATIONS AND THEIR INTERACTIONS ON THE TOTAL YIELDS OF SUDAX SX-11 AND GAHI-1 AND PERCENTAGES OF YIELD PRODUCED AFTER AUGUST 1 AT THREE LOCATIONS, 1969

Source of Variation Sudax SX-11	d.f.	Mean Squares Total Yield	Mean Squares Yield After Aug. 1	Source of Variation Gahi-1	d.f.	Mean Squares Total Yield	Mean Squares Yield After Aug. 1
Knoxville							
Soil type (S)	1	0.16	0.02	Soil type (S)	1	0.43*	0.01
Planting (P)	1	2.22*	0.97*	Planting (P)	1	0.81*	1.89*
Irrigation/Non-irrigation (I)	1	0.12	0.18	Irrigation/Non-irrigation (I)	1	0.17	0.03
S X P	1	1.30*	0.19	S X P	1	1.09*	0.01
S X I	1	0.01	0.15	S X I	1	0.22	0.02
P X I	1	0.00	0.02	P X I	1	0.14	0.47*
Residual	25	0.24	0.09	Residual	21	0.08	0.05
Spring Hill							
Soil type (S)	1	1.48	0.61	Soil type (S)	1	0.17	1.85*
Planting (P)	1	6.37*	0.00	Planting (P)	1	3.56*	1.49*
Irrigation/Non-irrigation (I)	1	0.41	0.00	Irrigation/Non-irrigation (I)	1	0.01	0.00
S X P	1	0.35	0.46	S X P	1	0.04	0.01
S X I	1	0.34	0.00	S X I	1	0.01	0.08
P X I	1	2.15	1.79	P X I	1	0.36	0.00
Residual	17	0.69	0.41	Residual	17	0.31	0.14
Jackson							
Planting (P)	1	1.57	0.26	Planting (P)	1	0.17	0.66*
Irrigation/Non-irrigation (I)	1	0.11	0.20	Irrigation/Non-irrigation (I)	1	0.08	0.01
P X I	1	0.62	0.30	P X I	1	0.04	0.06
Residual	13	0.66	0.10	Residual	12	0.09	0.04

* $P < .05$.

TABLE XXI

POPULATIONS OF CORN, GRAIN SORGHUM AND FORAGE SORGHUM PLANTS SEEDED ON TWO DATES AT SIX LOCATIONS INVOLVING 12 DIFFERENT SOIL TYPES, 1965-1969

Location	Crop	Soil	Planting Date	Year 1969	1968	1967	1966	1965	Mean
Knoxville	Corn	Sequoia		39.37*	41.00	35.41	32.64	56.81	41.04§
	silage	Sequatchie		38.87	41.32	33.67	31.39	59.55	40.96
			Early	48.83	42.93	34.54	31.64	51.08	41.80
			Late	29.40	39.40	34.57	32.39	65.28	40.20
Springfield	Corn	Dickson		53.82	55.81	48.33	. . .	. . .	52.65§
	silage	Huntington		55.81	53.82	52.32	. . .	. . .	53.98
			Early‡	55.81	56.31	51.32	. . .	. . .	54.48
			Late	53.82	53.32	49.33	. . .	. . .	52.16
Martin	Corn	Grenada		48.25	45.42	45.89	. . .	. . .	46.52
	silage	Collins		41.63	45.89	45.89	. . .	. . .	44.47
			Early	45.42	46.84	47.78	. . .	. . .	46.68
			Late	44.47	44.47	43.99	. . .	. . .	44.31
Spring Hill	Corn	Maury		51.16	54.24	54.67	. . .	. . .	53.36§
	silage	Emory		45.18	54.67	51.80	. . .	. . .	50.55
			Early	48.50	55.52	52.42	. . .	. . .	52.15
			Late	47.83	53.39	54.05	. . .	. . .	51.76
Jackson	Corn	Dexter		40.86	44.85	50.32	. . .	. . .	45.34§
	silage	Loring		40.36	51.33	51.32	. . .	. . .	47.67
			Early‡	43.35	55.31	51.82	. . .	. . .	50.16
			Late	37.87	40.86	49.82	. . .	. . .	42.85
Crossville	Corn	Tilsit		42.85	. . .	. . .	. . .	. . .	. . .
	silage	Hartsells		46.84	. . .	. . .	. . .	. . .	. . .
			Early	45.84	. . .	. . .	. . .	. . .	. . .
			Late	43.85	. . .	. . .	. . .	. . .	. . .

TABLE XXI (continued)

Location	Crop	Soil	Planting Date	Year 1969	1968	1967	1966	1965	Mean
General Mean	Corn	All soils		46.05	48.26	46.92	32.64	56.81	. . .
	silage			44.78	49.41	47.00	31.39	59.55	. . .
			Early	47.96	51.38	47.58	31.64	51.08	. . .
			Late	42.87	46.29	46.35	32.39	65.08	. . .
Knoxville	Grain	Sequoia		251.85	152.16	100.59	115.61	212.53	166.55§
	sorghum	Sequatchie†		478.09	169.78	97.98	182.88	228.73	231.49
			Early	449.38	173.63	86.04	101.91	204.81	203.15
			Late	280.55	148.32	112.54	196.59	236.45	194.89
Springfield	Grain	Dickson		423.57	331.88	476.88	. . .	. . .	410.78§
	sorghum	Huntington		380.71	330.38	579.03	. . .	. . .	430.04
			Early‡	409.62	332.38	398.14	. . .	. . .	380.05
			Late	394.67	329.88	657.76	. . .	. . .	460.77
Martin	Grain	Grenada		302.78	341.09	326.89	. . .	. . .	323.59§
	sorghum	Collins		335.42	337.31	264.44	. . .	. . .	312.39
			Early	327.38	326.43	282.89	. . .	. . .	312.23
			Late	310.82	351.98	308.44	. . .	. . .	2]2.73
Jackson	Grain	Dexter		483.37	458.95	596.33	. . .	. . .	512.88§
	sorghum	Loring		704.12	345.33	602.77	. . .	. . .	550.74
			Early‡	659.28	380.71	299.29	. . .	. . .	446.43
			Late	528.22	423.57	899.81	. . .	. . .	617.20
Crossville	Grain	Tilsit		279.06	. . .	. . .	. . .	. . .	. . .
	sorghum	Hartsells†		225.74	. . .	. . .	. . .	. . .	. . .
			Early	244.18	. . .	. . .	. . .	. . .	. . .
			Late	260.62	. . .	. . .	. . .	. . .	. . .

TABLE XXI (continued)

Location	Crop	Soil	Planting Date	Year 1969	1968	1967	1966	1965	Mean
General Mean	Grain	All soils		348.13	321.02	375.17	115.61	212.53	. . .
	sorghum			424.82	295.70	386.06	182.88	228.73	. . .
			Early	417.97	303.29	266.59	101.91	204.81	. . .
			Late	354.98	313.44	494.64	196.59	236.45	. . .
Knoxville	Forage	Sequoia		172.82	154.41	82.56	96.18	393.22	179.84[§]
	sorghum	Sequatchie		204.66	132.62	112.97	150.49	319.65	184.08
			Early	163.36	136.47	97.77	43.85	497.07	187.70
			Late	214.11	150.56	97.77	202.82	215.80	176.21
Springfield	Forage	Dickson		360.78	277.56	457.45	. . .	. . .	365.26[§]
	sorghum	Huntington		314.44	295.50	576.56	. . .	. . .	395.50
			Early	358.29	274.57	457.93	. . .	. . .	363.60
			Late	316.93	298.49	576.07	. . .	. . .	397.16
Martin	Forage	Grenada[†]		265.87	329.27	253.56	. . .	. . .	282.90[§]
	sorghum	Collins		240.22	271.55	196.32	. . .	. . .	236.03
			Early	266.82	287.64	198.21	. . .	. . .	250.89
			Late	239.27	313.18	251.67	. . .	. . .	268.04
Jackson	Forage	Dexter		489.85	344.34	173.40	. . .	. . .	335.86[§]
	sorghum	Loring		478.88	294.51	155.89	. . .	. . .	309.76
			Early[‡]	630.87	309.46	162.37	. . .	. . .	367.56
			Late	337.86	329.39	166.93	. . .	. . .	278.06
Crossville	Forage	Tilsit		218.26	. . .	. . .	. . .	. . .	. . .
	sorghum	Hartsells		231.22	. . .	. . .	. . .	. . .	. . .
			Early[‡]	203.31	. . .	. . .	. . .	. . .	. . .
			Late	246.17	. . .	. . .	. . .	. . .	. . .

TABLE XXI (continued)

Location	Crop	Soil	Planting Date	Year					Mean
				1969	1968	1967	1966	1965	
General Mean	Forage sorghum	All soils		301.52	276.40	241.74	96.18	393.22	. . .
				293.88	248.55	260.44	150.49	319.65	. . .
			Early	324.53	252.04	229.07	43.85	497.07	. . .
			Late	270.87	272.91	273.11	202.82	215.80	. . .

* = Population expressed in thousands/ha.

† = Mean difference in plants/ha between two soils for all years at a location, $P < .05$.

‡ = Mean difference in plants/ha between early and late plantings for all years at a location, $P < .05$.

§ = Mean difference between soils among years at a location, $P < .05$.

TABLE XXII

AVAILABLE SOIL MOISTURE AT THE END OF EACH MONTH OF THE GROWING SEASON FOR 12 SOIL TYPES AT SIX LOCATIONS, 1965-1969

				Available Soil Water Status				
Location	Soil	Depth	Year	May	June	July	Aug.	Sept.
		cm		mm				
Knoxville	Sequoia	127	1969	80	131	70	75	88
	Sequatchie	152		190	240	179	184	197
	Sequoia	127	1968	226	209	205	91	37
	Sequatchie	152		335	318	314	200	147
	Sequoia	127	1967	182	123	196	176	114
	Sequatchie	152		291	232	305	285	223
	Sequoia	127	1966	219	143	82	116	130
	Sequatchie	152		328	252	191	225	239
	Sequoia	127	1965	160	100	48	0	0
	Sequatchie	152		270	209	158	80	64
Springfield	Dickson	76	1969	206	132	16	0	0
	Huntington	162		527	454	337	307	220
	Dickson	76	1968	245	112	35	0	0
	Huntington	162		566	434	357	224	197
	Dickson	76	1967	220	160	159	72	41
	Huntington	162		541	481	481	393	362
Martin	Grenada	152	1969	306	289	257	286	226
	Collins	152		378	362	329	359	299
	Grenada	152	1968	281	198	136	9	35
	Collins	152		354	271	209	82	108
	Grenada	152	1967	357	314	321	239	202
	Collins	152		430	386	394	312	274

TABLE XXII (continued)

Location	Soil	Depth	Year	Available Soil Water Status				
				May	June	July	Aug.	Sept.
		cm		mm				
Spring Hill	Maury	165	1969	447	363	279	256	326
	Emory	165		486	403	319	296	366
	Maury	165	1968	415	319	217	163	174
	Emory	165		455	358	257	202	213
	Maury	165	1967	546	531	571	534	493
	Emory	165		586	570	611	574	532
Jackson	Dexter	152	1969	376	295	162	160	130
	Loring	91		243	163	29	27	0
	Dexter	152	1968	423	336	222	96	151
	Loring	91		290	203	89	0	1
	Dexter	152	1967	461	390	358	292	268
	Loring	91		328	257	226	160	135
Crossville	Tilsit	58	1969	300	329	269	209	213
	Hartsells	84		344	373	313	253	257
General Mean	All soils			344	290	241	192	179

TABLE XXIII

REGROWTH YIELDS OF GRAIN SORGHUM AND FORAGE SORGHUM SEEDED ON TWO DATES AND TWO SOILS AT THREE LOCATIONS, 1965-1969

		Regrowth Yield						
		Year					Planting Date Ave.	
Location	Soil	1969	1968	1967	1966	1965	Early	Late
		t/ha					t/ha	
Grain Sorghum								
Knoxville	Sequoia	1.67	.31	.25	1.15	1.56	1.89	. .
	Sequatchie	2.24	1.89	.41	2.00	2.64	3.44	.23
Martin	Grenada	1.60	.56	4.61	. .	. .	2.72	1.78
	Collins	2.53	1.78	5.12	. .	. .	4.38	1.90
Jackson	Dexter	4.10	.39	.75	. .	. .	2.54	.99
	Loring	4.81	.65	.40	. .	. .	1.75	2.16
Forage Sorghum								
Knoxville	Sequoia	2.64	.27	. .	. .	.59	1.44	. .
	Sequatchie	4.99	1.28	. .	. .	1.30	3.03	. .
Martin	Grenada	4.59	1.04	. .	. .	. .	3.28	.47
	Collins	9.19	4.74	. .	. .	. .	6.15	3.14
Jackson	Dexter	4.87	.97	. .	. .	. .	2.89	1.03
	Loring	5.27	1.05	. .	. .	. .	2.32	1.98

TABLE XXIV

ANALYSES OF VARIANCE OF NUTRIENT UPTAKE OF CORN AND GRAIN SORGHUM PLANTS SEEDED ON TWO DATES AT EACH OF SIX LOCATIONS, INVOLVING 12 DIFFERENT SOIL TYPES, 1969

		Mean Squares									
		Corn					Grain Sorghum				
Location	d.f.	Ca	Mg	K	P	N	Ca	Mg	K	P	N
Knoxville											
Soils	1	154.8	251.5	475.3	205.8	540.9	60.7	141.2	201.0	16.3	898.9
Planting	1	823.3	898.9	3562.3	169.0	4530.2	77.4	82.4	1306.6	97.3	41.5
Residual	1	163.3	223.9	1886.4	249.8	3876.6	179.4	22.2	633.2	18.1	865.7
Knoxville											
Soils	1	36.3	87.5	102.9	163.8	80.2	69.9	180.5*	478.5	23.0	476.8
Planting	1	1227.2*	1477.5*	7218.5*	255.0	6144.0	35.8	51.4	935.9	188.8*	117.0
Irr./ Nonirr.	1	34.4	2.3	1564.1	0.0	1.6	4.4	1.7	635.2	0.1	193.5
Residual	4	98.3	116.1	900.1	81.2	1291.0	66.5	19.5	267.4	7.9	362.3
Springfield											
Soils	1	180.9	358.8	1060.2	717.6	13903.2	957.0	301.8	515.2	170.5	2399.1
Planting	1	25.4	34.0	4621.1	9.8	1833.2	36.6	78.4	702.7*	3.0	1842.8
Residual	1	190.1	65.1	319.6	128.2	1920.6	26.6	34.0	3.4	41.5	1270.4
Martin											
Soils	1	7.2	1.7	432.4	36.6	919.2	448.8	0.3	12866.1	153.4	1164.8
Planting	1	0.0	0.9	83.4	0.5	161.8	92.9	5.3	1056.5	1.7	567.3
Residual	1	19.1	30.8	356.7	0.8	20.6	25.4	19.6	1881.5	44.5	939.7
Spring Hill											
Soils	1	371.7	187.0	0.0	70.7	213.9	446.4	101.8*	1491.0	51.5	661.7
Planting	1	92.9	74.5	546.1	49.9	627.5	126.9	25.4	197.9	7.9	159.0
Residual	1	40.8	38.0	244.5	14.5	296.0	16.7	0.2	119.4	30.2	201.0

TABLE XXIV (continued)

		Mean Squares									
		Corn					Grain Sorghum				
Location	d.f.	Ca	Mg	K	P	N	Ca	Mg	K	P	N
Spring Hill											
Soils	1	530.1*	175.2	42.7*	232.8*	1542.2	850.7*	197.9*	1698.5	140.4	348.4
Planting	1	92.7	88.9	1068.8	94.3*	653.3	61.6	6.2	1423.2	22.2	63.4
Irr./ Nonirr.	1	31.2	25.7	1767.9	33.0	302.6	17.0	53.7	2769.4	67.3	1542.3
Residual	4	18.8	23.0	165.0	9.0	445.2	23.4	7.3	964.9	29.0	295.8
Jackson											
Soils	1	11.7	22.7	436.9	1.5	256.9	182.4	0.4	9.5	0.0	182.4
Planting	1	11.7	3.8	1.1	48.3	810.5*	201.0	28.9	244.5	18.1	60.7
Residual	1	10.4	44.5	55.6	1.8	3.6	36.0	54.7	237.5	3.2	10.2
Jackson											
Planting	1	6.4	27.2	61.6	3.4	455.9	905.7	239.2	957.0*	6.4	19.1
Irr./ Nonirr.	1	94.0	58.9	1246.5*	64.2	1696.7	5.3	0.1	2.8*	53.9	249.8
Residual	1	6.9	11.7	2.1	14.1	27.2	98.4	7.3	0.1	73.5	235.8
Crossville											
Soils	1	66.0	90.8	1601.1	95.1	1871.8	255.1	70.7	1142.0	18.1	87.6
Planting	1	16.7	39.4	5.5	24.3	12.1	515.2	11.3	4060.2	19.1	1331.0
Residual	1	19.6	9.2	43.7	0.6	1145.8	89.7	4.1	644.5	4.1	40.6

* $P < .05$.

TABLE XXV

BULK DENSITY VALUES BY SOIL TYPE AND HORIZON

Soil Type	Horizon	Depth cm	Bulk Density Value g/cc
Sequoia	Ap	0-15.2	1.28
	A1-B1	15.2-24.1	1.28
	IIB2t-A1	24.1-38.1	1.30
Sequatchie	Ap	0-27.9	1.60
	B1	27.9-38.1	1.62
	B21t	38.1-63.5	1.66
Dickson	Ap	0-30.5	1.30
	B21t	30.5-55.9	1.43
	B'21tx	55.9-76.2	1.47
Huntington	Ap	0-27.9	1.30
	B21	27.9-43.2	1.34
	B22	43.2-63.5	1.40
Grenada	Ap1	0-15.2	1.24
	Ap2	15.2-30.5	1.24
	B21	30.5-55.9	1.26
Collins	Ap	0-15.2	1.42
	IIA1	15.2-30.5	1.42
	IIB1	30.5-50.8	1.45
Maury	Ap	0-25.4	1.40
	B21t	25.4-53.3	1.48
	B22t	53.3-86.4	1.52
Emory	Ap	0-17.8	1.47
	B21t	17.8-43.2	1.54
	B22t	43.2-61.0	1.50
Dexter	Ap	0-15.2	1.32
	B21t	15.2-35.6	1.39
	B22t	35.6-61.0	1.40
Loring	Ap1	0-15.2	1.32
	Ap1	15.2-24.1	1.32
	B21	24.1-45.7	1.42
Tilsit	Ap	0-12.7	1.35
	A3	12.7-25.4	1.38
	B1	25.4-40.6	1.56
Hartsells	Ap	0-25.4	1.37
	B21	25.4-45.7	1.53
	B22	45.7-71.7	1.60

VITA

William Eugene Bryan was born in Hillsboro, Tennessee, February 25, 1934. He received his elementary education at Stephenson Elementary School. He graduated from Manchester Central High School in June 1952. The following September he entered Tennessee Technological University, receiving the Bachelor of Science degree in Agricultural Education in June 1956. In September 1956, he began a two-year tour of duty in the United States Army Signal Corps. After serving in Korea, he was released from active duty and worked a year at Tullahoma, AEDC. In September 1959, he entered the Graduate School of the University of Tennessee, serving as assistant in Agronomy under the guidance of Dr. W. L. Parks. After receiving the Master of Science degree in Agronomy in June 1961, he began a career with the University of Tennessee, Agricultural Extension Service, working as Assistant Agricultural Extension Service Agent in Cannon County. In 1965, he accepted a position as specialist with the University of Tennessee, Agricultural Extension Service. In January 1967, he transferred to Chattanooga, Tennessee, as supervisor with the University of Tennessee, Agricultural Extension Service. He is a member of Alpha Zeta, Alpha Tau Alpha, Gamma Sigma Delta, Epsilon Sigma Phi, American Society of Agronomy, County Agents Association, and is listed in Who's Who in American Colleges and Universities.

He is married to the former Shirley Ann Ray of Manchester, Tennessee. They have three children: Timothy Loy; Stephen Kent; and Mary Catharine.