To the Graduate Council:

I am submitting herewith a thesis written by David Wilson Monks entitled "Yield and Growth Rate of Sweet Potatoes As Influenced by Transplant Orientation." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant and Soil Science.

Wayne J. McLaurin

Wayne J. McLaurin, Major Professor

We have read this thesis
and recommend its acceptance:

Dennis E. Deyton

David L. Coffey

Accepted for the Council:

L Evans Roth

Vice Chancellor
Graduate Studies and Research

A

YIELD AND GROWTH RATE OF SWEET POTATOES AS INFLUENCED BY TRANSPLANT ORIENTATION

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

David Wilson Monks

June 1981

ACKNOWLEDGMENTS

The author is greatly indebted to Dr. Wayne J. McLaurin, who, as the author's major professor, has given friendship, support and advice throughout the experimentation and manuscript preparation for this study. The author also expresses appreciation to Dr. David L. Coffey, the author's academic advisor, for his suggestions, guidance and encouragement, as well as the constructive review of this manuscript.

The author also expresses special appreciation to the following: To Dr. Dennis E. Deyton for his review of the manuscript and friendship throughout the course of study. To John Willingham for his assistance and advice throughout the experimentation. To Dr. Lloyd F. Seatz and The University of Tennessee Agricultural Experiment Station for their cooperation and financial assistance.

To fellow graduate students, particularly Charles S. Williams, for their aid and fellowship during the graduate program. A special thanks to Ms. Alma Ramsey and Ms. Carolyn Drake for typing the manuscript.

The author is indebted to his parents, Mr. and Mrs. Albert W. Monks, and his inlaws, Mr. and Mrs. Charlie Emberton, for their moral support and encouragements.

The author is deeply appreciative to his wife, Denise, for her patience, support and inspiration throughout his educational career.

ABSTRACT

Field experiments were conducted at Fayetteville and Knoxville, Tennessee to (1) provide information on seasonal growth patterns and growth characteristics of 'Centennial' and 'Jewel' sweet potatoes, (2) compare growth characteristics and marketable yield between vertically and horizontally orienting slips of these cultivars at planting, and (3) determine alternate methods for measuring leaf area of sweet potato plants. Treatments consisted of 'Centennial' and 'Jewel' each having vertical and horizontal slip orientations. Treatments were arranged in a split plot design and were replicated eight times.

Vertically oriented 'Centennial' plants produced a higher percentage of number one grade roots and a greater marketable yield than horizontally oriented plants of the same cultivar. Plant orientation appeared to have little or no effect on grade or marketable yield of 'Jewel.'

Generally, horizontally oriented slips of 'Centennial' and vertically oriented slips of 'Jewel' maintained larger leaf areas, more roots per plant and greater root dry matter accumulation than the other planting orientation of the respective cultivar.

Dry matter accumulation by both cultivars began as early as 30 days from planting and by 60 days one-third of the total root dry matter accumulation for the season had occurred. An inverse relationship was found between stem growth rate and root growth rate; as one increased the other slowed. Horizontally oriented slips of both cultivars had larger diameter developing roots at most harvest dates than

vertically oriented plants. No difference in plant survival between slip orientations was observed.

Relatively strong correlations were obtained between root dry matter accumulation and mean developing root diameter and between root dry matter accumulation and stem dry weight for each cultivar. For both cultivars, weaker correlations were found between number of developing roots per plant and root dry matter accumulation and between number of developing roots and mean developing root diameter.

Methods based on the midvein length and fresh weight were found to correlate highly with an automatic area meter (Hayashi Denko, Model AAM-5) for determing leaf area.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The sweet potato plant (Ipomoea batatus (L.) Poir.) is widely grown for its edible roots which have been used as a food for at least five centuries (14).

The sweet potato is a popular vegetable crop in the South because it lends itself to fresh, as well as canned products. However, due to the great labor requirement necessary for harvesting the crop and changing food habits, sweet potato acerage has declined in recent years. Reports (6,48) indicate that Tennessee had 2,000 acres in sweet potato production in 1980 as compared to 3,200 acres in 1973.

The sweet potato plant, consisting of leaves, flowers, and edible roots, is a tropical perennial that is vegetatively propagated and consists of a short stem having many runners (25,28).

Various research workers have found inconclusive effects of slip orientation at planting on yield of sweet potatoes (11,37). Seasonal growth patterns and growth characteristics of currently popular sweet potato cultivars, 'Centennial' and 'Jewel,' have not been studied in detail. The objectives of this study were to (1) provide information on seasonal growth patterns and growth characteristics of 'Centennial' and 'Jewel,' (2) compare growth characteristics and marketable yield between vertically and horizontally oriented slips of 'Centennial' and 'Jewel' cultivars, and (3) determine alternate methods for measuring leaf area of sweet potato plants.

CHAPTER II

REVIEW OF LITERATURE

History, Production and Economical Importance

The sweet potato (*Ipomoea batatas* (L.) Poir,), a member of the Convolvulaceae or morning glory family, originated in tropical America and was cultivated by the Mayans and the Peruvians by the latter part of the fifteenth century. Sweet potatoes were first cultivated in a temperate climate by the primitive tribes of New Zealand and were grown in Virginia as early as 1648 (14,25,26,28,33). Today, sweet potatoes are grown in both tropical and subtropical regions of the world (46).

Total world population of sweet potatoes in 1961 was 108,300,000 metric tons. Of this, the United States produced 701,000 tons, China 2,979,000, Indonesia 2,709,000 tons and Japan led world production with 6,277,000 metric tons (15).

The sweet potato has declined in popularity in the U. S. over the years but still ranked ninth in 1977 in acreage and eleventh in value of the 22 principal vegetable crops. Sweet potato acreage declined from 472,000 acres in 1949 to 113,000 acres in 1977. Average yield per acre has more than doubled from 52.5 hundred weight in 1939 to 110 hundred weight in 1977. Production decreased from 24,804,000 to 12,395,000 hundred weight for the same period of time (25,48).

Martin *et al*. (33) noted in 1959 that about 72 minutes of human labor were required to produce 100 pounds of sweet potatoes in the United

States. There has been a sharp decline in production of this crop in recent years due to heavy labor requirements. The white potato (Solanum tubersum) crop, by use of completely mechanized harvesters, was produced with a labor requirement of only 11 minutes per 100 pounds (33). According to Ware and McCollum, today sweet potatoes are harvested using a combination of hand labor and partially mechanized equipment (48).

In the United States the sweet potato has become popular in the South, yet is grown as far north as New Jersey and as far west as central California (46). In 1980 North Carolina led in sweet potato production with 4,255,000 hundred weights, followed by Louisiana with 2,125,000, California with 1,530,000 and Texas with 520,000 hundred weights. Of these five, California led in the efficiency of sweet potato production with an average of 170 hundred weights per acre. North Carolina averaged 115, Louisiana 85, and Texas 80 hundred weights per acre, respectively (6).

Plant Anatomy and Nutrition

The sweet potato plant is a perennial which is grown as an annual in the United States. The flowers are violet or blue in color and are funnel-form. The leaves are weakly cordate and have either entire or sinuate edges (25,26,28).

There are over 400 species of the genus Ipomoea, the sweet potato being the only one producing edible roots. The sweet potato, botanically speaking, is not a tuber like the white potato, but a tuberous root having dormant shoots near lenticels. The edible roots have epidermis ranging in color from white to various shades of orange and red, and periderm ranging in color from white to several shades of orange (26,28,33,46).

According to Crosby (15), the sweet potato has an extremely low moisture content, among the lowest of any common vegetable. This makes the sweet potato a concentrated source of both major and minor nutritional constituents. The sweet potato also appears to have the highest non-sugar carbohydrate content of any vegetable food (15).

Howard et al. (24) indicated that the 'Porto Rico' sweet potato contains approximately 70% water, 2.0% protein, 0.2% fat, and 4.4% total sugar. Burton (10) reported that 100 g of sweet potato root contains approximately 30 mg of calcium, 49 mg of phosphorus, 0.7 mg of iron, 4 mg of sodium, and 530 mg of potassium. Howard et al. (24) also stated that 100 g of 'Porto Rico' sweet potato contains 7,700 I.U. of vitamin A, 0.09 mg of B_1, 0.05 mg of B_2, and 22 mg of vitamin C.

Measurement of Growth

Plant growth is measured in many different ways, including volume, dry weight, length, width, and area (30,34,43). Fresh weight is variable because of dependence on the water status of the plant and is not a reliable measure of growth. Therefore, due to the variation in fresh weight, volume measurements are sometimes made (43). Volume measurements are not always easily made and irreversible changes resulting from the water status of the plant must be taken into consideration. Growth measurements, therefore, are often based on other indices such as length, width, and area (43). Such measurements are directly related to volume and are valid, though indirect, measures of growth (30,34,43).

According to Leopold (43) and Mitchell (34) crop production is more accurately given by measurement of dry matter than by measurement of fresh weight. Mitchell (34) contended that dry weight increases reflected the accumulation of photosynthate and these weight increases were parallel to, but not the same as growth. Nichiporovich (35) defined biological yield as the total dry matter accumulation of a plant system. Mitchell (34) defined economic yield as the volume or weight of those plant organs that comprise the product of economic or agricultural value. The proportion of biological yield represented by economic yield is called the harvest index. This term implies the movement of dry matter to a useful organ (34).

Brougham (9) reported that both percentage of solar radiation interception and rate of dry matter production increased with leaf area development and both approached maximum at the same leaf area index. Watson (49) noted that diffusion of CO_2 into the leaf was likely to be more closely dependent on leaf area than on any other measureable attribute; and photosynthesis is limited by the rate of diffusion of CO_2 into the leaf. Watson also states that leaf area should be reported per unit area of land surface and termed leaf area index (LAI). Leaf area is often determined by removing leaves from the plant and measuring area by various means. This process is time-consuming, as well as destructive to the plant. Quicker, less-destructive methods are available for measuring leaf area (42,49).

Webb and Gorham (50) discovered that developing leaves of squash began exporting photo-assimilates when the plants reached 50% of their maximum dry weight. Mitchell (34) reported with peas and Hanway and Thompson (22) reported with soybeans that these plants increased in dry weight and then decreased, except for the fruiting body or storage organ which continued to increase. An annual plant stores much of its carbohydrates in the seed in contrast to a perennial plant which stores much of its carbohydrates in an overwintering organ, which, in the case of the sweet potato, is the root (33,34).

According to Radford (42) crop growth rate ($\overline{CGR}$) and relative growth rate ($\overline{RGR}$) are used in measuring the efficiency of plant growth. Noggle and Fritz (36) point out that relative growth rate has two components: (1) the rate of increase of dry weight per unit time per unit area of leaf surface, termed the net assimilation rate ($\overline{NAR}$); and (2) the ratio of leaf area to dry weight, termed the leaf area ratio (LAR). The net assimilation rate is an estimate of net photosynthesis and is determined by measuring plant dry weight (roots plus shoots) and leaf area in intervals during growth and is commonly reported as grams of dry weight per square centimeter of leaf surface per week. Watson (49) shows that a crop's maximum dry matter production occurs when maximum LAI coincides with the maximum $\overline{NAR}$ peak of the growing season. Leaf area ratio is a measure of the proportion of the plant which is involved in photosynthetic processes and is reported as the leaf area surface (cm^2) per gram of dry weight. Crop growth rate is expressed as dry weight (g) accumulated per unit of time (49).

The growth and development of the sweet potato plant comprises three distinct, though slightly overlapping phases: (1) an initial phase consisting of the growth of the vines and absorbing roots only; (2) an intermediate phase consisting of growth of vines and absorbing roots with initial development of the fleshy roots; and (3) a final phase consisting of a rapid development of fleshy roots (17). Scott

(44) discovered that both 'Maryland Golden' and 'Porto Rico' sweet potato cultivars produced vines only with no fleshy root development during the first 67 days of the growing season. Formation of fleshy roots or root thickening was first observed at 80 days. One-third of total root growth for the season was noted between 96 days and 111 days from transplanting; after 111 days the dry weight of the 'Porto Rico' shoots exceeded the dry weight of the vines. Both cultivars produced limited vine growth during fleshy root formation (44).

Cultural Practices

Edmond and Ammerman (17) recommend that methods of seed plant selection be classified as follows: either (1) annual mass selection of high producing hills within a seedstock planting or (2) annual mass selection of high producing hills within a foundation planting, or (3) single hill selection. All off-type or diseased roots should always be discarded (12,17,33,46).

In the early days of commercial production,researchers maintained that the fleshy roots contained all of the materials necessary for the growth of transplants (21,46). Anderson (2), however, discovered that sawdust plus the application of a nitrogen carrier produced 2,360 more plants per bushel of sweet potato roots than sawdust alone. Pope (40) observed that an addition of 8-8-8 mixture of fertilizer at the rate of 12 oz. per square yard produced an additional 800 plants per bushel of bedded roots. Research results have led to recommending the addition of fertilizer to the bedding medium for optimum sweet potato production (12,16,17,33,40).

Sweet potato specialists have recommended that seed roots for plant production be placed as close as possible in the bed without contact with each other (17,21). Edmond and Dunkleburg (18), by bedding twice the number of 'Porto Rico' roots per unit area of bedding space as recommended, noticed an increase in plant production per unit area of bed space, a marked reduction in the kilowatt hours of electricity required for plant production, and a decreased production in spindly plants with no increase in loss to disease.

Deonier and Kushman (16) found that bedding stock preheated before bedding and presprouted to a length of two inches produced more transplants at 43 days from bedding than seedstock that was not preheated. Presprouted stock also produced more slips in each of four pullings than untreated roots (16).

Hines (23) indicated that in Mississippi well drained silt loams produced from 20 to 30 more bushels of No. 1 'Porto Rico' roots per acre with acceptable periderm and carotene content than loams, sandy loams or light sandy loams. Researchers from the Norfolk producing district in Virginia, using the cultivars 'Virginian,' 'Porto Rico' and 'Maryland Golden,' found that sandy loams produced 140 to 250 more bushels of U. S. No. 1 per acre than the coarser sandy loams (5). Peterson et al.(39) observed that sandy loams produced 15 to 60 bushels per acre more than loamy sands.

Tennessee fertilizer recommendations for high yields of sweet potatoes are 20 to 60 pounds per acre of nitrogen, 80 to 120 pounds per acre of phosphorus and 80 to 150 pounds per acre of potassium (12,33). Anderson (3) found that 'Porto Rico' and 'Big Jersey' cultivars produced roots of larger diameter when fertilized with high ratios of potash to nitrogen than when fertilized with a low ratio of potash to nitrogen.

Jones et al. (27) observed that soils with less than 100 ppm of phosphorus before fertilization responded with an increase in number one roots with application of 120 to 150 pounds per acre of P_2O_5. Paterson and Speights (38) found that 'Porto Rico' showed an increase in number one roots with the addition of up to 50 pounds of actual nitrogen per acre with slight increases in yields with 50-100 pounds of nitrogen added per acre.

Price (41) determined that 14 inches was optimum with-in row spacing for the 'Porto Rico' sweet potato. Cochran (13) found that spacing within rows had less effect on the total and U. S. No. 1 yields of 'Porto Rico' than did delayed plantings. He also reported the optimum planting date for Georgia to be April 16-25 for this variety (13). Anderson and Randolf (4) noted that planting 'Porto Rico' plants April 15-25 produced roots of larger diameter than did planting in either May or June.

Research indicates that early plantings produce roots containing more carotene than late plantings and that older, more mature plants have roots containing more carotene than roots of less mature plants (4,17,19,29). Kimbrough et al. (29) also found that 120 days was necessary for the 'Porto Rico' to develop maximum carotene content. According to Ezell and Wilcox (20) a high percentage of carotene in sweet potato roots is important because it is a precursor of Vitamin A and because it influences internal color which is an important criterion utilized in the selection of improved strains (20). By extracting the pigments and analyzing them through chromatography, Ezell and Wilcox (20) showed that beta carotene(s) make up the majority of the pigments contained in the sweet potato root.

Park _et al_. (37) planted sweet potato plants lengthwise (horizontally) on ridges with only the green portion of the plant projecting vertically above the soil. At harvest, evidence from their research hinted at higher yields and better-shaped roots from these plants as compared with conventionally vertically oriented transplants (37). Chen _et al_. (11) reported similar results and indicated that horizontal-transplanted 'Centennial' and 'Jewel' plants had higher survival rates, better root systems, more marketable but smaller roots when compared to vertical-transplanted plants of the same cultivars.

Edmond _et al_. (19) found yield increases of up to 20 bushels per acre for 'Porto Rico' plants transplanted on twelve inch ridges as opposed to plants planted on level land. Plants grown on fifteen inch ridges also produced 30 to 60 bushels per acre more No. 1 roots than plants grown on three inch ridges (19). Woodard (51) furnished evidence showing that by increasing ridge height from eight inches to fifteen inches, marketable yield was increased.

Beattie _et al_. (7), using the cultivars 'Nancy Hall,' 'Porto Rico,' and 'Yellow Jersey,' compared six to seven inch transplants with nine to ten inch transplants and obtained no difference in yields provided they were all sturdy, vigorous plants. Loomis (31) found that large, six-leaf transplants outyielded plants having two or three leaves by up to 70 bushels per acre. The close relationship of stand and yield has led to a recommendation that transplants less than six inches in height be discarded (2,7,17).

Price (41) declared that a twenty-five percent or less reduction in foliage density of 'Porto Rico' had no influence on yield or average root weight. Edmond and Ammerman (17) maintained that as long as clipped or unclipped 'Porto Rico' transplants are similar in weight total root yield from them should be the same.

Tomkins and Horton (47) found that 'Centennial' and 'Julian' transplants outyielded seed pieces by 35-55%. Lutz et al. (32) indicated similar results with the cultivars 'Porto Rico' and 'Triumph.'

Harvesting and Grading

Scott and Bouwkamp (45) propose that the time of the harvest of sweet potato roots is normally determined by the size of marketable roots, weather conditions, and/or economic factors rather than by any index of physiological maturity of the crop.

The members of the S-101 Technical committee propose that sweet potatoes be sized as follows: (1) U. S. number one-small, 6.3-7.5 cm diameter and 10.0-22.5 cm length; (2) U. S. number one-medium, 7.5-8.7 cm diameter and 10.0-22.5 cm length; (3) U. S. number one-large, 8.7-10.0 cm diameter and 10-22.5 cm length; (4) U. S. jumbo, 10.0 cm and greater in diameter but not more than 567.0 g in weight; and (5) U. S. canners, 2.5-5.8 cm diameter and 5.0-17.5 cm length (1).

CHAPTER III

METHODS AND MATERIALS

Field experiments were conducted in Tennessee in 1980 on the Plant and Soil Science farm near Knoxville and on the Roy Clarence Wallace farm near Fayetteville.

General Procedure

Yield Study

Slips were planted in Fayetteville (Baxter silt loam) on May 30, 1980 and at Knoxville (Sequatchie fine sandy loam) on June 2, 1980. Soil tests were made at both locations and fertilized according to Tennessee recommendations for commercial sweet potato production.

The four treatments consisted of 'Centennial' and 'Jewel' sweet potato cultivars each having vertical and horizontal root orientations. Treatments were arranged in a split plot design and were replicated eight times. Individual plots consisted of 1 row 9.3 m in length. Rows were spaced 1.2 m apart and plants were spaced 30.5 cm apart in the row.

The plant bed was prepared using a mold board plow followed by disking in the early spring. Later, beds were formed using a lister-bedder.

'Centennial' and 'Jewel' seed roots were bedded in hot beds on April 15, 1980 and plants (slips) were pulled when they reached approximately 30 cm (May 30). At this stage each plant had approximately the same number of nodes.

Plants were transplanted by hand by making a furrow on top of the pre-formed beds. Each plant was placed in this furrow and oriented vertically or horizontally and covered with soil making sure about 15 cm of plant tissue was beneath the soil surface. Extreme care was employed to insure similar numbers of nodes were placed under the soil surface for each root orientation.

Vernolate (2.2 kg/ha) and diphenamid (4.5 kg/ha) were used to control annual grasses and broadleaf weeds at Fayetteville and Knoxville, respectively. Weeds escaping these treatments were removed by mechanical cultivation and hand-hoeing.

Stand counts were taken four weeks after transplanting at both locations.

Roots were harvested and graded 120 days after planting as suggested by the Sweet Potato Collaborators (1).

Growth Study

An adjacent planting was devoted to a growth study with cultural practices identical to those used in the yield study. Stand counts were taken four weeks after transplanting at both locations.

Treatments were identical to those employed in the yield study. Each treatment consisted of 1 row plots spaced 1.2 m wide and 1.6 m long with an in-row spacing of 30.5 cm between plants. Each treatment was replicated eight times.

Two replications consisting of four plants each were harvested 30, 60, 90, and 120 days after transplanting and measurements of growth parameters were recorded. Parameters measured at each harvest interval included leaf fresh weight, leaf dry weight, leaf area, stem fresh weight, and stem dry weight. Root development was recorded at each time interval by measuring fresh root weight, dry root weight, root volume, and diameter of each developing root.

Data Collection and Calculations

Yield Study

At 120 days after planting, the roots were harvested and graded into the following categories: (1) canners, (2) number one-small, (3) number one-medium, (4) number one-large, and (5) jumbo. Each category was sized according to standards suggested by the Sweet Potato Collaborators (Table 1).

Growth Study

Leaf measurements. Leaves were removed from each plant and total fresh weight was determined. Leaf area was calculated by subsampling and using the ratio method described by Watson (49). Subsamples were dried in a forced air oven at 70^{o}C for 24 hours; percent dry matter was calculated. Total leaf dry weight per plant was tabulated using percent dry matter. Net assimilation rate ($\overline{NAR}$), crop growth rate ($\overline{CGR}$), relative growth rate ($\overline{RGR}$) and leaf area index (LAI) were tabulated by formulas suggested by Watson (49) and Leopold (30).

Stem measurements. Stem fresh weights and dry weights were determined by a similar procedure described for leaves in the previous section.

Root development. The root system was removed from each plant and all developing roots (over 3 cm in diameter) and fibrous roots were

TABLE 1. Sweet Potato Root Grades as Set by the Sweet Potato Collaborators.

Grade	Root Size: Diameter (cm)	Root Size: Length (cm)
Number one-small	6.3-7.5	10.0-22.5
Number one-medium	7.5-8.7	10.0-22.5
Number one-large	8.7-10.0	10.0-22.5
Jumbo	10.0 >	22.5 >
Canners	2.5-5.8	5.0-17.5

cleaned and fresh weights were determined separately. Total fresh weight was calculated by summing these two weights. Diameter of developing roots was measured with a caliper to the nearest one-tenth centimeter with measurement at the widest cross section on the root. Average root diameter was calculated on a per plant basis. Root volume measurements were made by placing the total root system into a water-filled 19 liter container and measuring water displacement. Core samples were obtained from a random number of roots from each plant, weighed to the nearest one-hundredth gram, and dried in a forced air oven at 70°C for 24 hours. Dry matter percentages were calculated and multiplied by total root fresh weight for determination of total root dry matter of each plant.

Elemental analysis. Plant leaf tissue samples were collected randomly at Knoxville at each 30 day harvest period. Samples were dried in a forced air oven for 24 hours at 70°C. The samples were ground with a Wiley Mill fitted with a 2 mm screen and were stored until analyzed.

Magnesium, calcium and potassium analyses were done on the Perkin-Elmer 5000 atomic absorption spectrophotometer from a 0.5 g sample after a wet digestion procedure (8). Phosphorus was done on the Technicon autoanalyzer after a wet digestion procedure (8).

Leaf Area Study

Leaves from the first, third, fifth, and seventh node, proximal to the apex of a 90 cm runner, were collected on September 10, 1980 from 25 'Centennial' plants at Knoxville, Tennessee. Leaf data was recorded on a per leaf basis. The length of the leaf midvein was measured by hand followed by leaf area determination using an automatic area meter (Hayashi Denko, Model AAM-5).[1] Fresh weight of each leaf was determined. Regression analyses were conducted to determine if leaf midvein length or fresh weight is strongly enough correlated with leaf area as to provide an alternate method to an automatic area meter for determining leaf area in sweet potatoes.

Statistical Analysis

Analysis of variance was calculated and the least significant difference test used to detect significant differences among the treatment means. The statistical analyses were performed by The University of Tennessee Computer Center and Statistical Analysis System.

[1]Automatic area meter is a photo-electronic apparatus used to measure the total area of the test objects by determining how much the test objects shadow the scanning light.

CHAPTER IV

RESULTS AND DISCUSSION

Results from studies conducted at Fayetteville and Knoxville, Tennessee will be discussed together unless otherwise specified.

Yield Study

No statistical differences in yields were observed between horizontally and vertically oriented 'Centennial' at Fayetteville and Knoxville, however production trends were observed at both locations (Table 2). Contrary to results reported by Chen _et al_. (11), vertically oriented 'Centennial' at Fayetteville yielded 289 kg more total marketable roots and 1662 kg more U. S. number one roots per hectare than horizontally oriented plants of the same cultivar (Table 2). Similarly, the vertically oriented 'Centennial' at Knoxville yielded 3156 kg more total marketable roots per hectare and 2264 kg more U. S. number one roots per hectare than horizontally oriented plants of the same cultivar (Table 2). Results indicated no statistical yield differences or consistent production trends of vertical or horizontal root orientations of 'Jewel' at Fayetteville or Knoxville (Table 3). These findings were unlike results published by Chen _et al_. (11), who reported that horizontally oriented plants of 'Jewel' produced more marketable roots than vertically oriented plants.

TABLE 2. Yield of Horizontally and Vertically Oriented 'Centennial' Sweet Potatoes at Fayetteville and Knoxville, Tennessee, 1980

		Yield (kg/ha)				
Plant Orientation	Location	Jumbos	No. 1*	Canners	Total	Percent 1
Horizontal	Fayetteville	100	9437	11185	20722	44.6
Vertical	Fayetteville	178	11099	9734	21012	52.5
Horizontal	Knoxville	1061	14322	10747	26130	55.0
Vertical	Knoxville	154	16586	12546	29286	56.6
LSD, 0.05		NS	NS	NS	NS	NS

*Sum of all number ones (small + medium + large).

TABLE 3. Yield of Horizontally and Vertically Oriented 'Jewel' Sweet Potatoes at Fayetteville and Knoxville, Tennessee, 1980

Plant Orientation	Location	Yield (kg/ha)				
		Jumbos	No. 1*	Canners	Total	Percent 1
Horizontal	Fayetteville	138	10119	7190	17448	59.6
Vertical	Fayetteville	0	9936	8195	18131	54.1
Horizontal	Knoxville	0	15875	10247	26122	59.2
Vertical	Knoxville	46	16513	8902	25461	64.0
LSD, 0.05		NS	NS	NS	NS	NS

*Sum of all number ones (small + medium + large).

Growth Study

Horizontally oriented 'Centennial' plants generally maintained a larger leaf area index (LAI) throughout the growing season than vertically oriented plants of the same cultivar (Figures 1-A, 1-B). With the exception of the 120 day harvest at Knoxville, plants of 'Jewel' from all other harvests maintained a larger leaf area index during the growing season at both locations when roots were oriented vertically than when roots were horizontally oriented (Figures 2-A, 2-B).

The results of this study show that dry matter accumulation or carbohydrate storage in developing roots, as calculated by multiplying fleshy roots at each harvest by percent dry weight, begins as early as 30 days from transplanting for both cultivars studied (Figures 3,4). This is in contrast to findings of Scott (44), who reported that root thickening or dry matter accumulation in developing roots for 'Porto Rico' and 'Maryland Golden' began approximately 80 days from transplanting.

A weak, but statistically significant correlation ($r \simeq .45$) was found between leaf area index and root dry matter accumulation, therefore growth curves for these two growth parameters were similar (Figures 3,4). Root dry matter for 'Centennial' was generally higher throughout the growing season from slips which were horizontally oriented at planting (Figures 3-A, 3-B). Root growth leveled off after 90 days at Fayetteville but proceeded linearly at Knoxville up to 120 days. With the exception of the 120 day harvest at Knoxville and the 60 day harvest at Fayetteville, 'Jewel' exhibited the greatest amount of root dry matter at each harvest in plants having vertical oriented

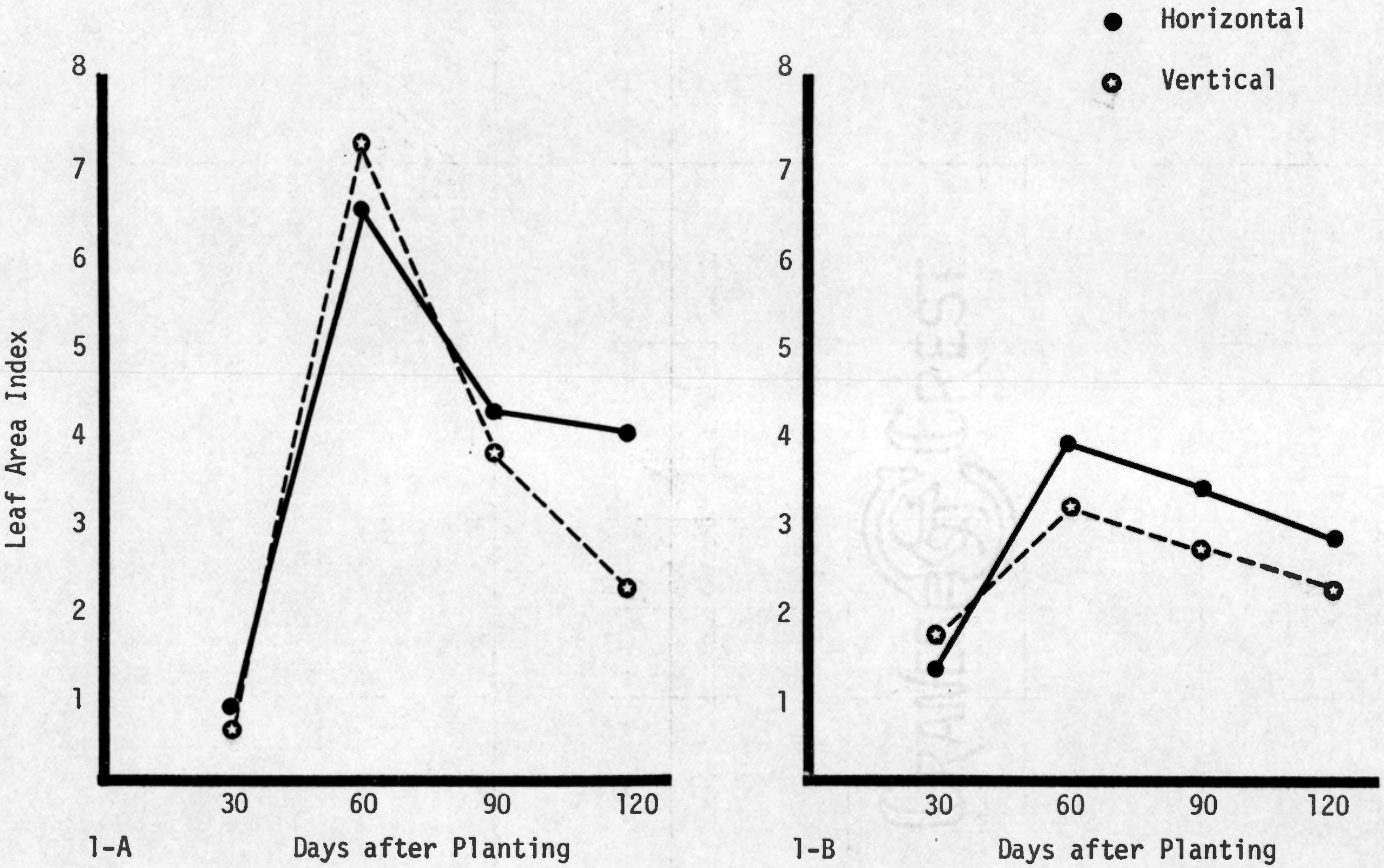

Figure 1. Influence of vertical and horizontal root orientations on seasonal leaf area of 'Centennial' plants at Fayetteville (1-A) and Knoxville (1-B), Tennessee, 1980.

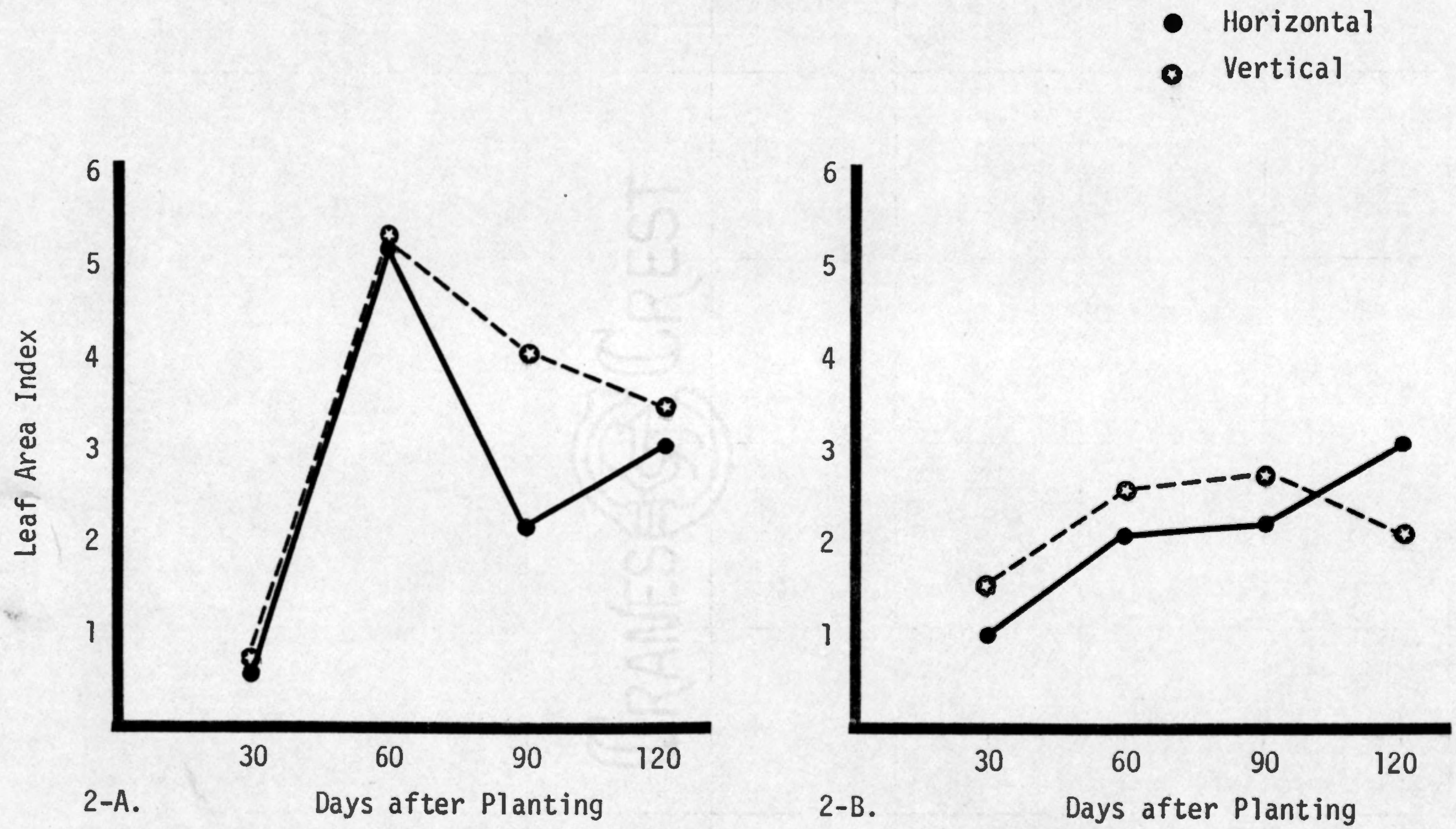

Figure 2. Influence of vertical and horizontal root orientations on seasonal leaf area of 'Jewel' plants at Fayetteville (2-A) and Knoxville (2-B), Tennessee, 1980.

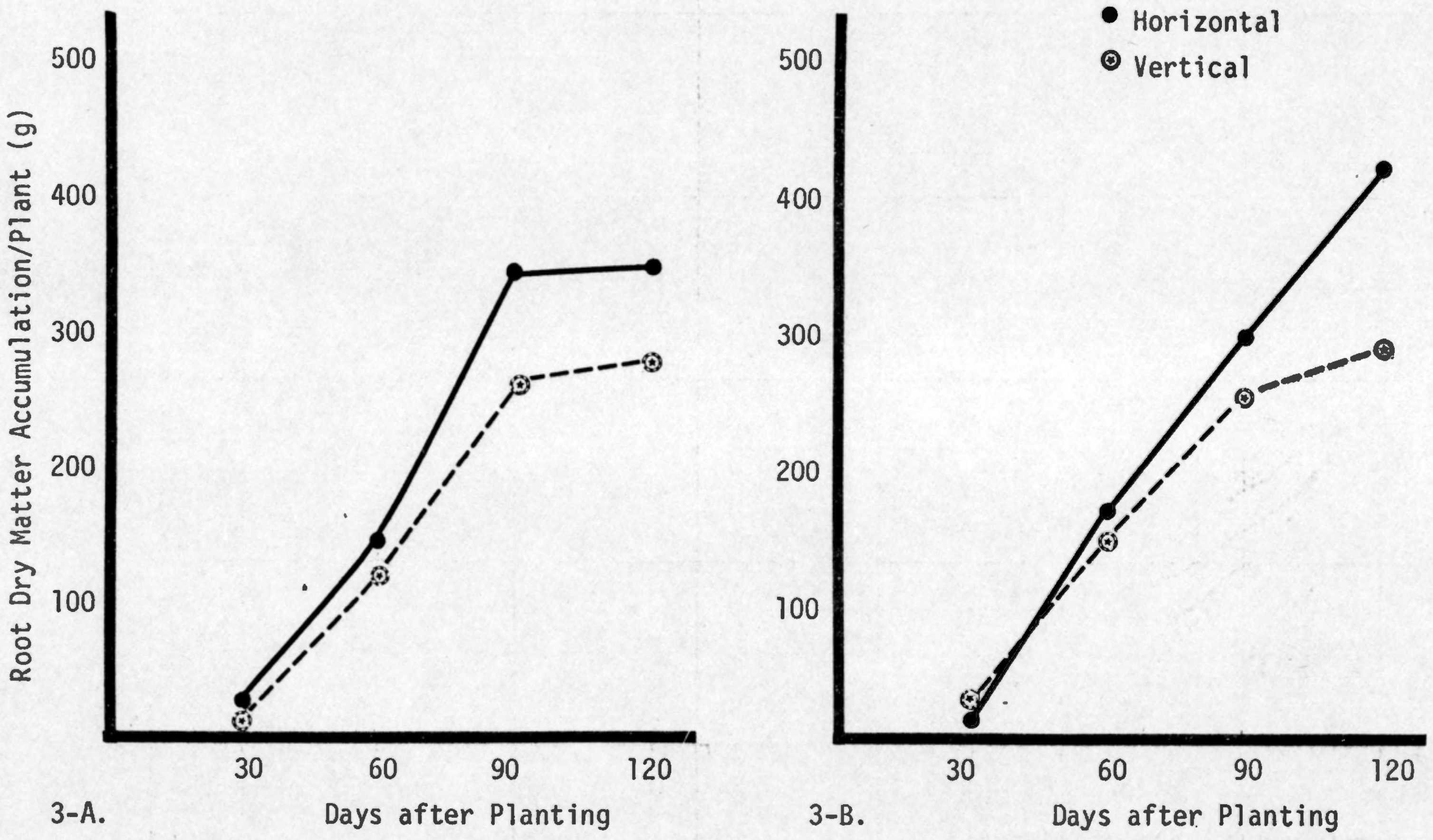

Figure 3. Influence of horizontal and vertical root orientation on root dry matter accumulation of 'Centennial' plants at Fayetteville (3-A) and Knoxville (3-B), Tennessee, 1980.

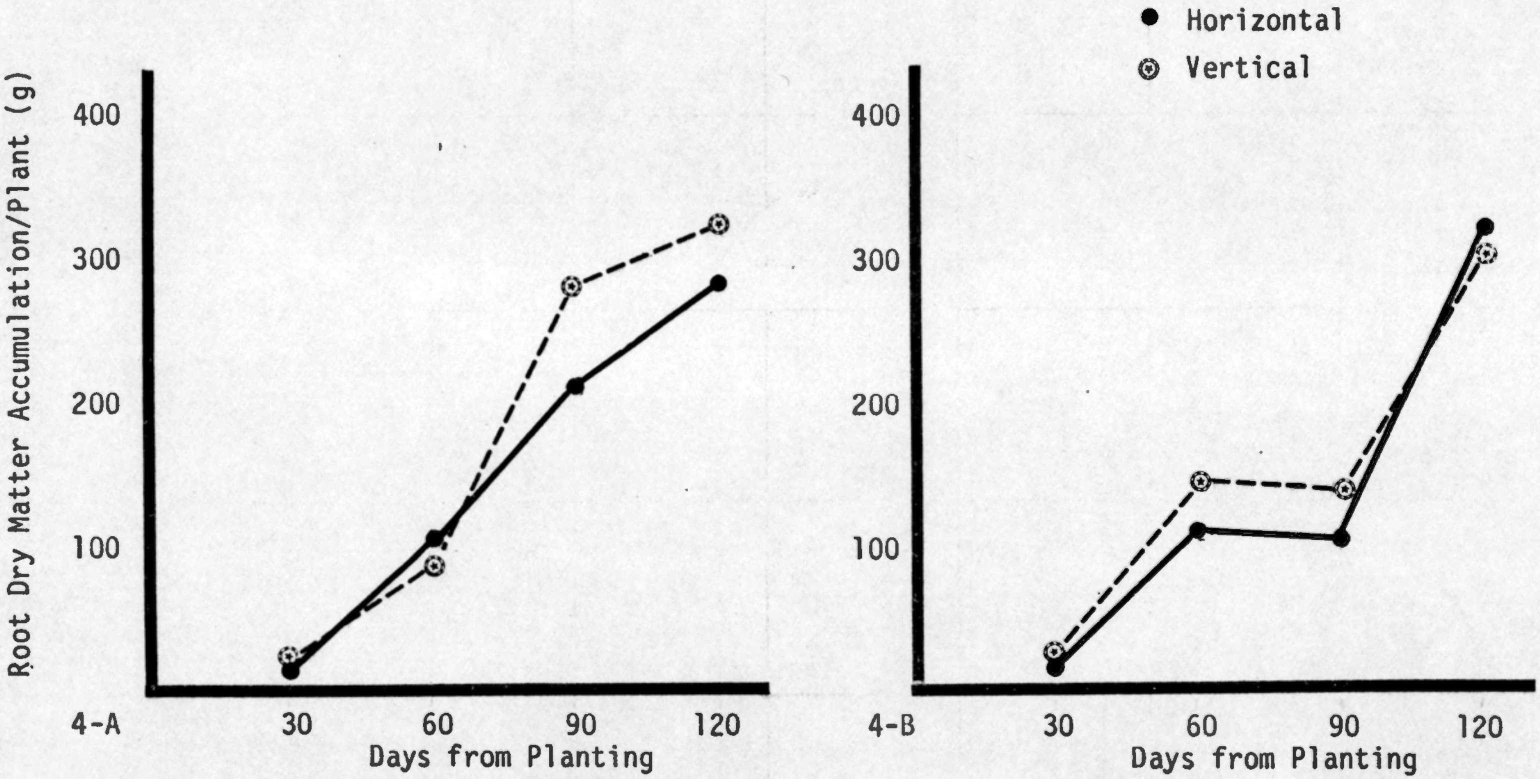

Figure 4. Influence of horizontal and vertical root orientation on root dry matter accumulation of 'Jewel' plants at Fayetteville (4-A) and Knoxville (4-B), Tennessee, 1980.

roots (Figures 4-A, 4-B). Larger root dry weights of vertical oriented 'Jewel' were observed during the latter part of the growing season at Fayetteville (Tables 4-A, 4-B). Due to extremely high temperatures and severe drought all over Tennessee during early season, root growth of vertical 'Jewel' at Knoxville was apparently greater because of irrigation supplied at this location at this time. Late season rains in Fayetteville apparently boosted "vertical" root growth over "horizontal" root growth (Tables 4-A, 4-B). Root volume measurements also substantiated these growth patterns of both cultivars (Figures 5,6).

One-third of total seasonal growth of 'Centennial' and 'Jewel' having either root orientation was noted 60 days after transplanting (Figures 4,5). Scott (44) reported one-third of total root growth to occur between 90 and 111 days from transplanting for 'Maryland Golden' and 'Porto Rico.' Apparently 'Centennial' and 'Jewel' are earlier maturing cultivars than 'Maryland Golden' and 'Porto Rico.' This may be the basis for popularity among commercial producers for 'Centennial' and 'Jewel' sweet potatoes.

As suggested by Edmond (17), as carbohydrate is utilized for foliage growth in sweet potatoes, less carbohydrate is available for translocation into storage roots. This may possibly explain why, with the exception of growth period three (60-90 days) of 'Centennial,' an inverse relationship was found between stem growth rate and root growth rate of both cultivars, as one increased the other slowed (Figures 7,8). From both orientations at both locations during growth period three (60-90 days), stem growth parallelled root growth for 'Centennial' (Figures 7-A, 7-B). Apparently during growth period three (60-90 days) 'Centennial' plants produced sufficient photosynthate for growth and

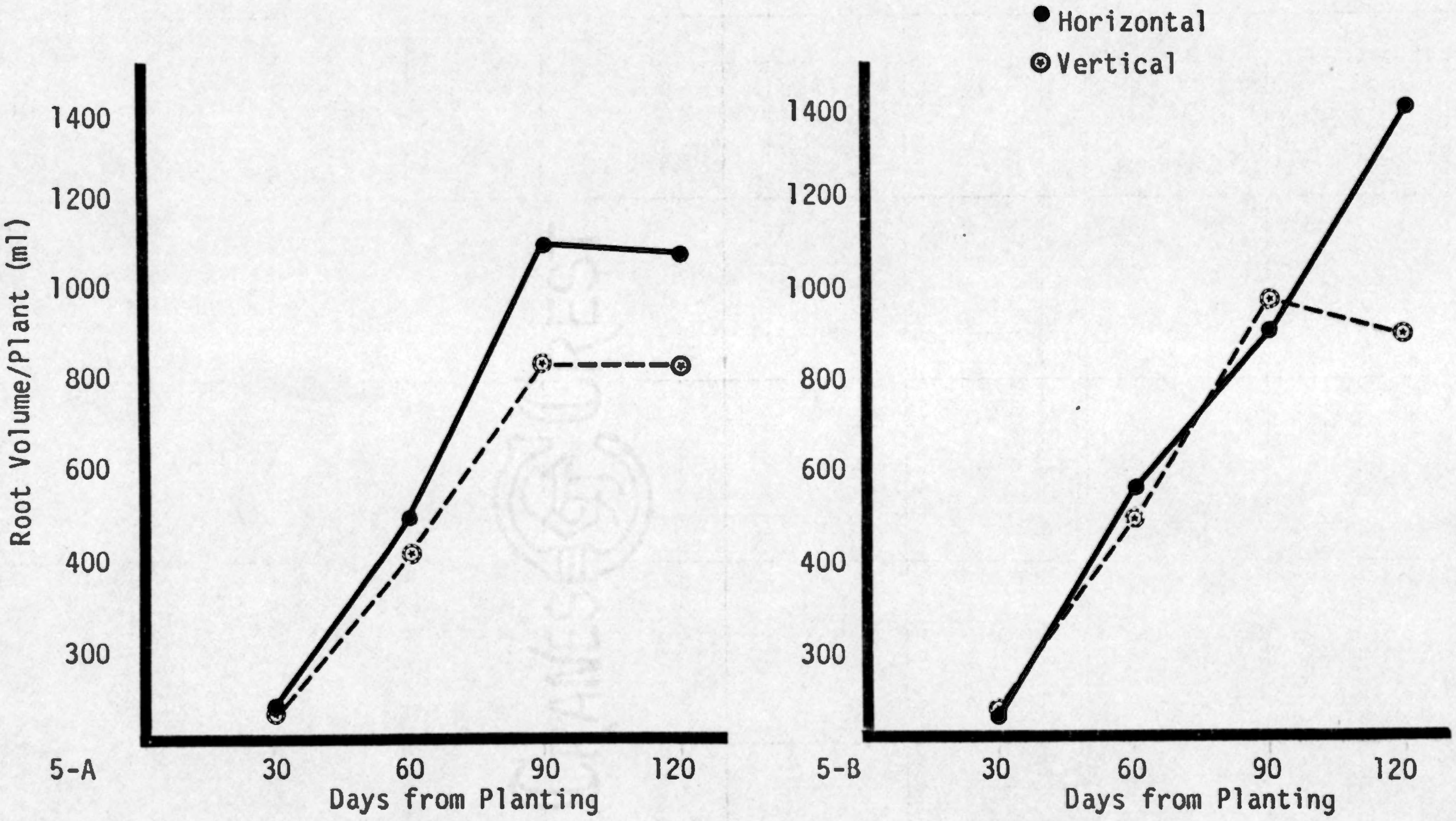

Figure 5. Influence of horizontal and vertical root orientation on root volume of 'Centennial' plants at Fayetteville (5-A) and Knoxville (5-B), Tennessee, 1980.

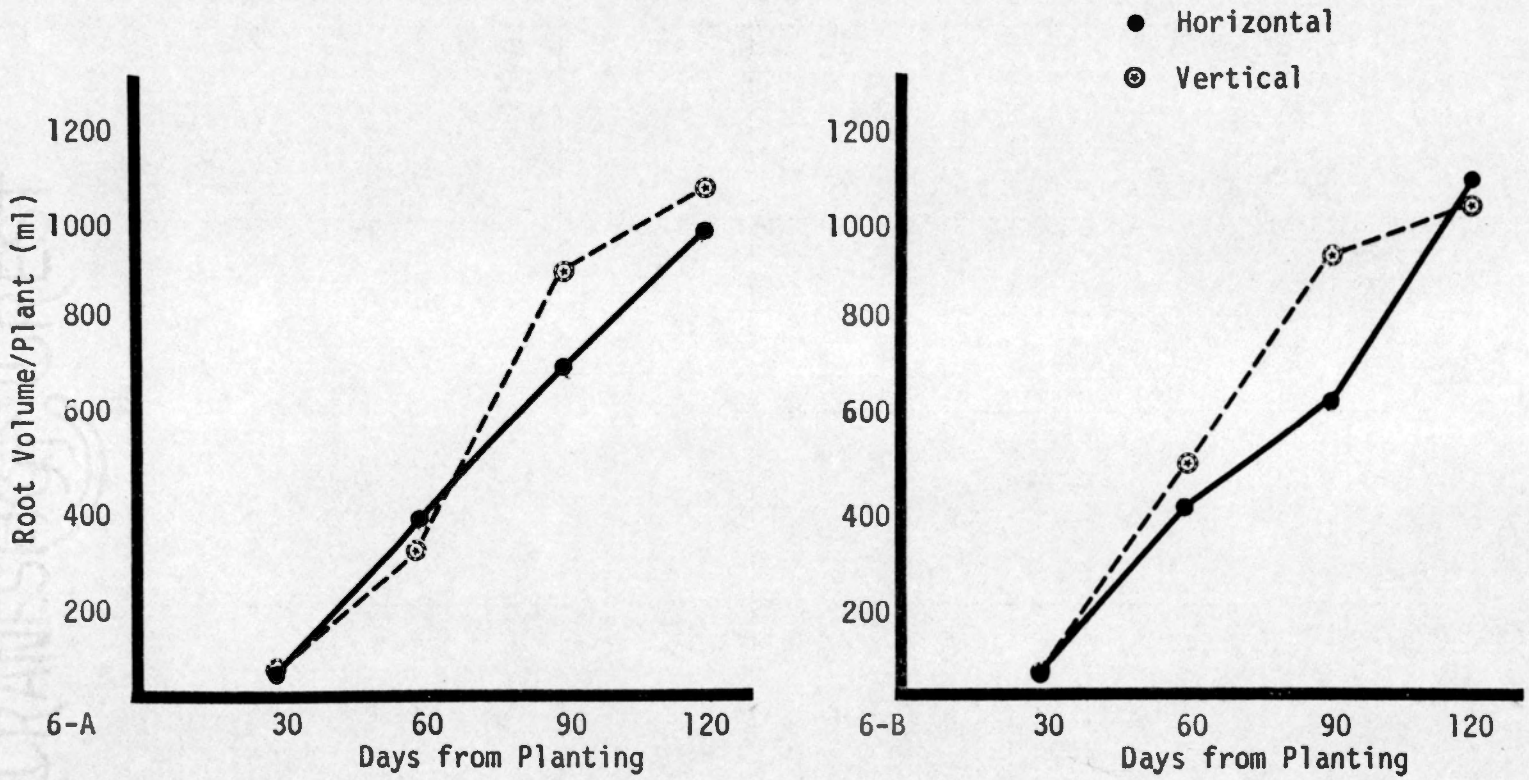

Figure 6. Influence of horizontal and vertical root orientation on root volume of 'Jewel' plants at Fayetteville (6-A) and Knoxville (6-B), Tennessee, 1980.

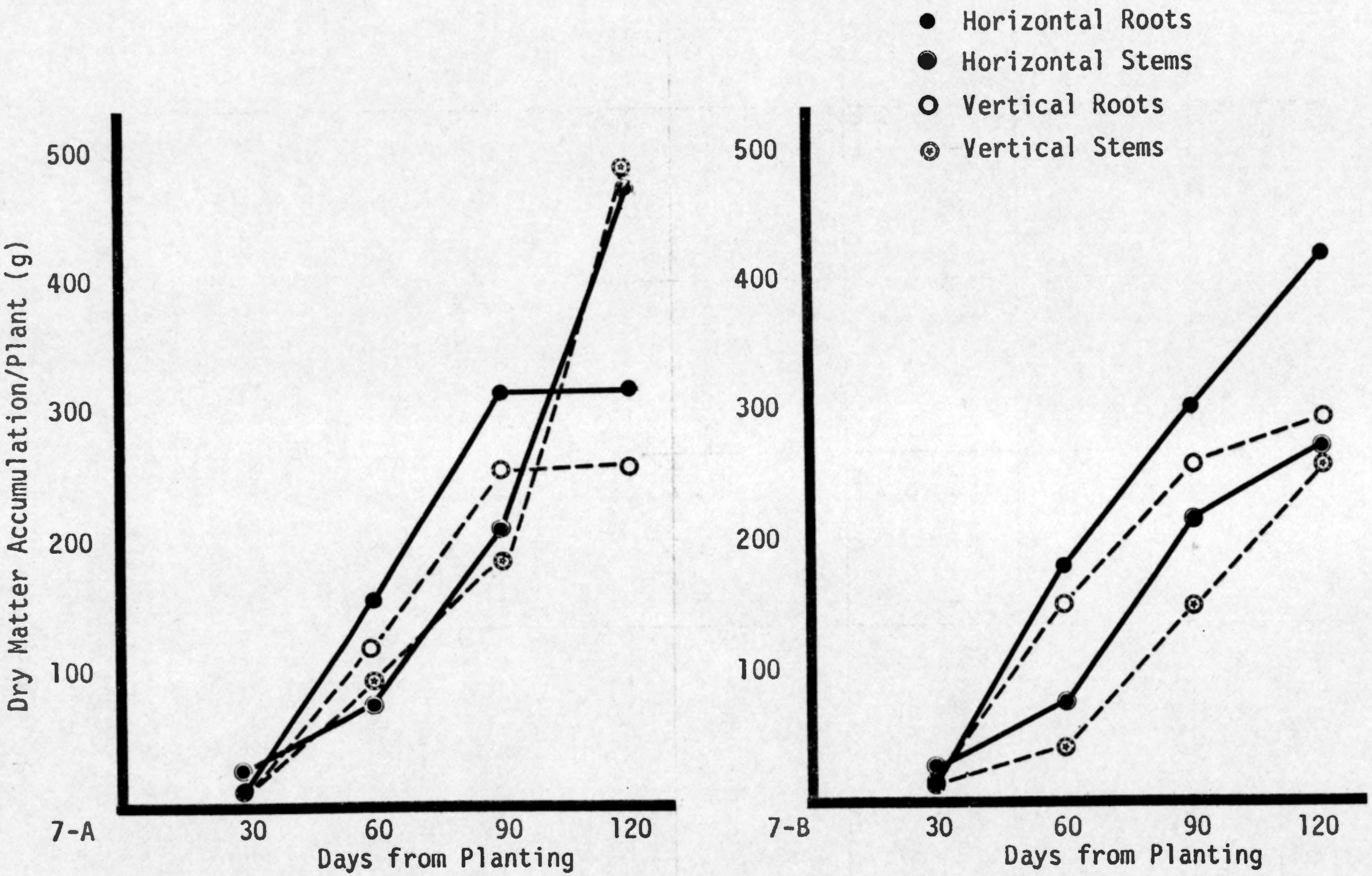

Figure 7. Simultaneous growth of stems and roots of horizontally and vertically oriented 'Centennial' plants at Fayetteville (7-A) and Knoxville (7-B), Tennessee, 1980.

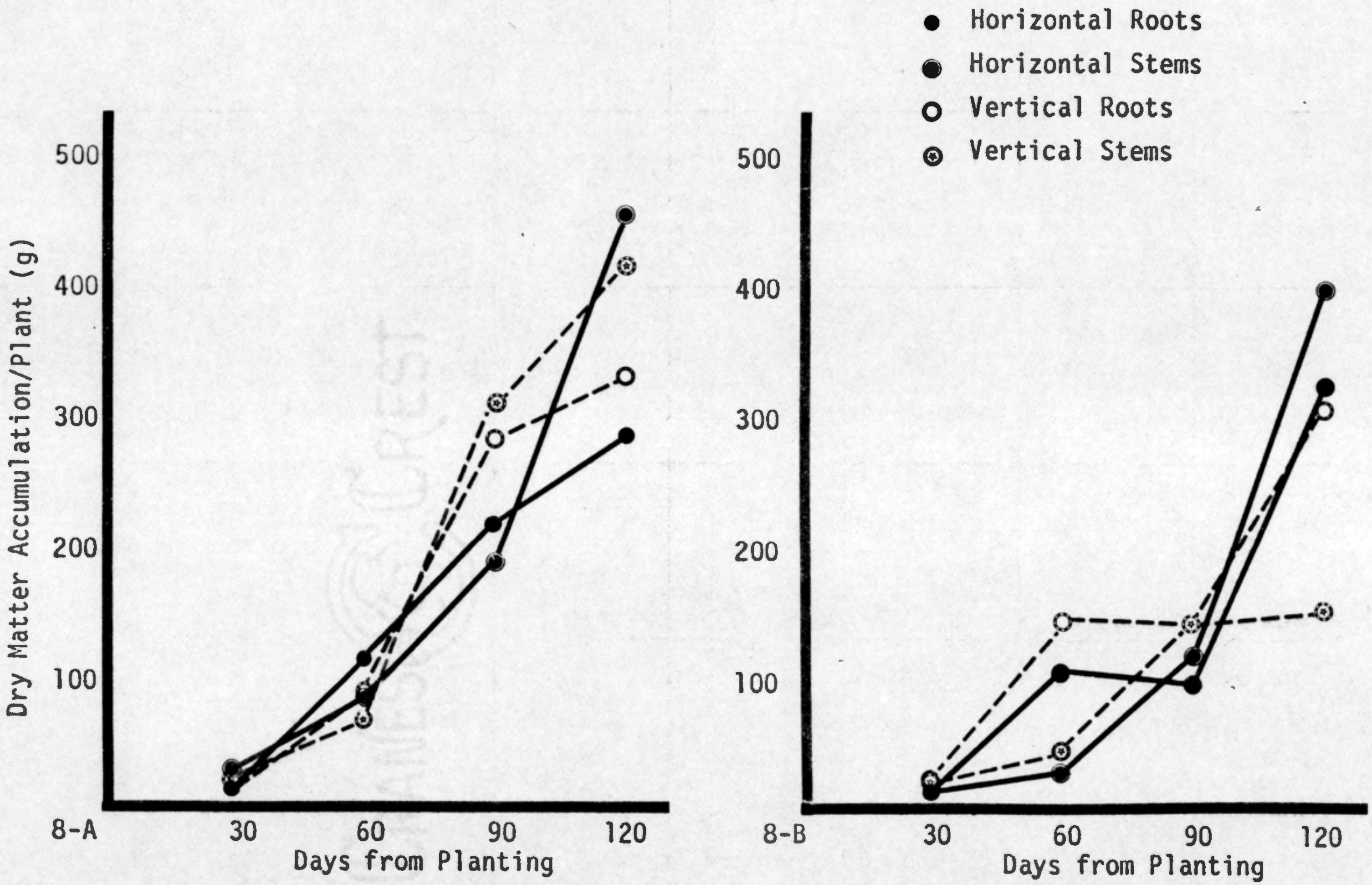

Figure 8. Simultaneous growth of stems and roots of horizontally and vertically oriented 'Jewel' plants at Fayetteville (8-A) and Knoxville (8-B), Tennessee, 1980.

starch accumulation to continue simultaneously.

The number of developing roots per 'Centennial' plant at Fayetteville was higher for plants having horizontal root orientation than plants having vertical orientation (Figure 9-A). 'Centennial' plants produced sufficient photosynthate for growth and starch accumulation to continue simultaneously.

The number of developing roots per 'Centennial' plant at Fayetteville was higher for plants having horizontal root orientation than plants having vertical orientation (Figure 9-A). 'Centennial' plants having either root orientation at Knoxville had similar numbers of developing roots at 60 and 90 days from planting. After 120 days, plants having horizontally oriented roots produced considerably more developing roots than plants having vertically oriented roots (Figures 9-B). With the exception of the 120 day harvest at Knoxville, vertically oriented 'Jewel' at both locations produced more developing roots per plant than horizontally oriented plants (Figures 10-A, 10-B). The number of developing roots per plant also decreased for vertical 'Centennial' between the 60 and 90 day harvests and for horizontal 'Centennial' between the 90 and 120 day harvests at Fayetteville and Knoxville, respectively (Figure 9). Vertical 'Jewel' after the 60 day harvest at both locations indicated a reduction in number of developing roots per plant (Figure 10). Apparently, reduction of developing roots between harvests was due to experimental error since different plants were harvested at each harvest date. Each cultivar having either horizontally or vertically orientations produced maximum number of developing roots per plant by 60 days from planting (Figures 9,10).

With exception of the 90 day harvests of 'Jewel' at Knoxville and

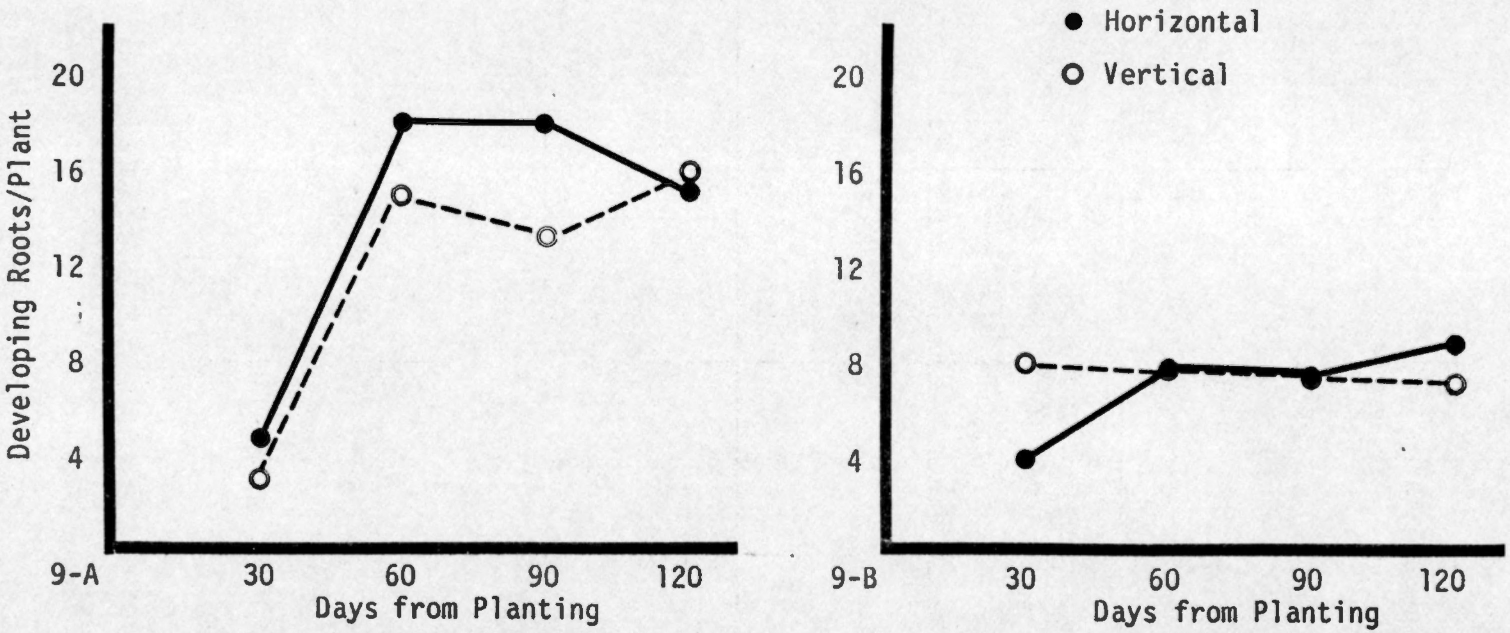

Figure 9. Influence of root orientation on the number of developing roots per 'Centennial' plant at Fayetteville (9-A) and Knoxville (9-B), Tennessee, 1980.

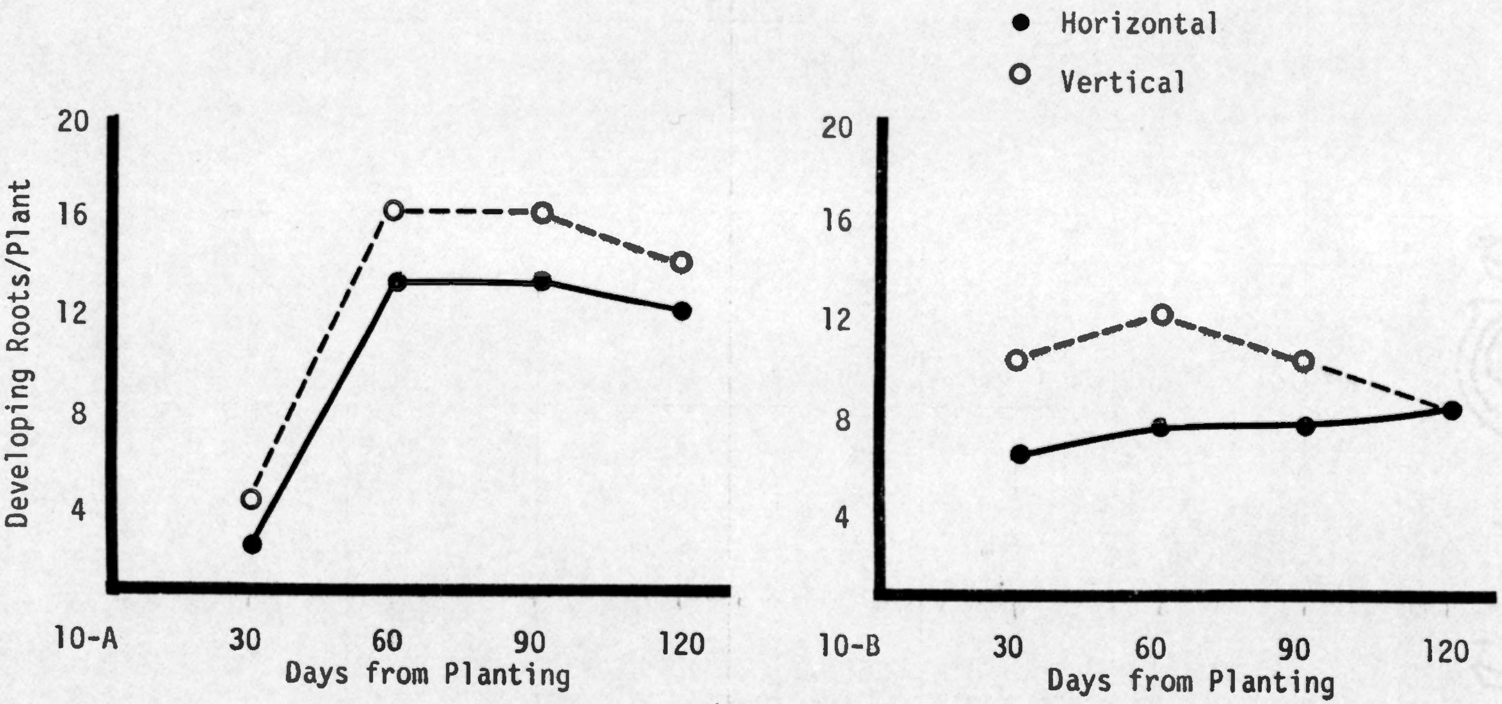

Figure 10. Influence of root orientation on the number of developing roots per 'Jewel' plant at Fayetteville (10-A) and Knoxville (10-B), Tennessee, 1980.

'Centennial' at Fayetteville, mean diameter of developing roots from plants of both cultivars was greater for plants horizontally oriented than for plants vertically oriented (Figures 11,12).

In contrast to the findings of Chen et al. (11), Fayetteville and Knoxville results showed no differences in plant density or survival rate between horizontal and vertical orientations of "Centennial" or 'Jewel.'

Due to wide variations of relative growth rate (ranged from 0.05 g/g/day to 0.10 g/g/day), crop growth rate (ranged from 0.2 g/day to 16.0 g/day) and net assimilation rate (ranged from 0.4 mg/cm^2/day to 1.4 mg/cm^2/day) among treatments, no conclusive effects of orientations and cultivars on these parameters were obtained.

Leaf Area Study

Leaf midvein length and leaf fresh weight were found to be highly correlated with leaf area (Table 4). These methods for measuring leaf area would provide a rapid means for leaf area determination. When a rapid, non-destructive process for measuring leaf area is necessary, measurement of leaf midvein would prove useful. When preservation of intact leaves is not desirable, a rapid method for leaf area determination would be leaf fresh weight.

Growth Parameters

Leaf area index (LAI), developing root number (DRN), mean developing root diameter (MDR), root dry matter accumulation (DMA), and stem dry weight (DWS) for both root orientations from Fayetteville and Knoxville were combined and correlation coefficients determined for

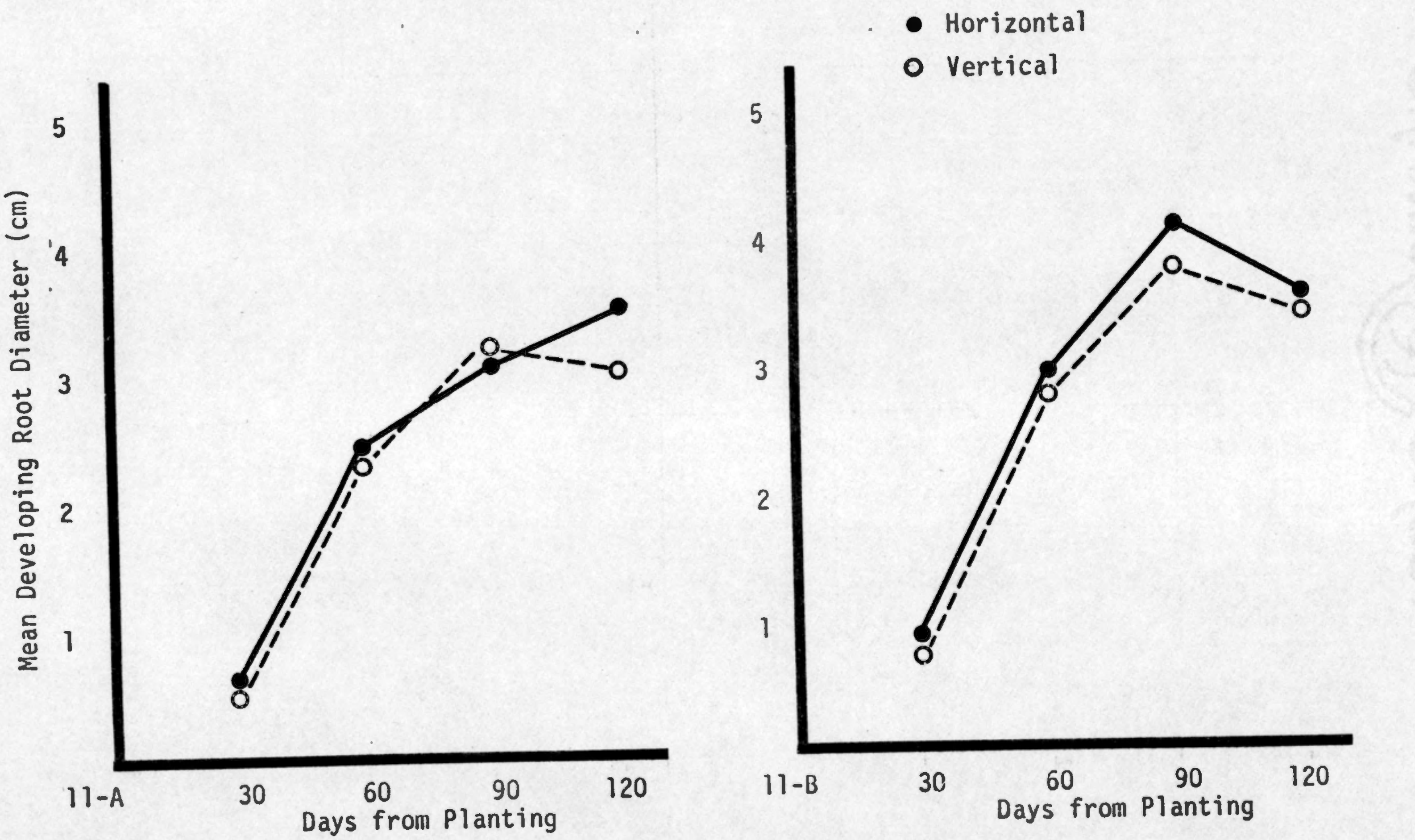

Figure 11. Influence of root orientation on mean developing root diameter of the 'Centennial' cultivar at Fayetteville (11-A) and Knoxville (11-B), Tennessee, 1980.

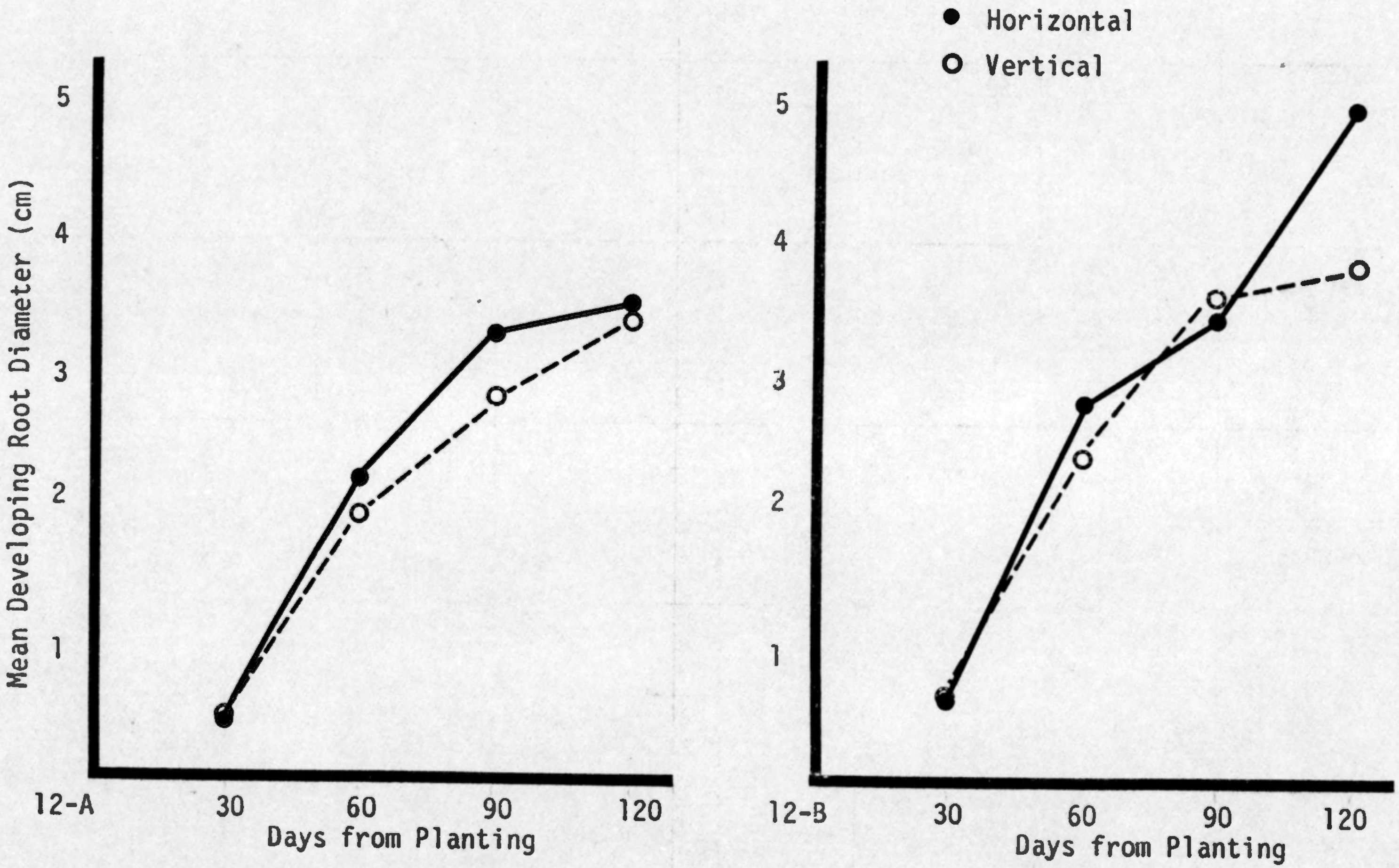

Figure 12. Influence of root orientation on mean developing root diameter of the 'Jewel' cultivar at Fayetteville (12-A) and Knoxville (12-B), Tennessee, 1980.

TABLE 4. Correlation of Leaf Measurements and Leaf Area and Value of Constants (Y = A + BX).

Leaf from Node Number	Leaf Measurement	r	A	B
One*	Midvein length	0.919	-32.5	11.7
	Fresh weight	0.982	-4.2	46.3
Three	Midvein length	0.926	-49.0	14.4
	Fresh weight	0.934	8.8	42.3
Five	Midvein length	0.821	-37.5	13.7
	Fresh weight	0.968	10.9	42.1
Seven	Midvein length	0.922	-87.8	18.6
	Fresh weight	0.748	63.7	22.3

*First open leaf.

these parameters to provide general information about 'Centennial' and 'Jewel' cultivars (Tables 5,6).[2]

In contrast to the weak correlation of the number of developing roots per plant to root dry matter accumulation, mean developing root diameter per 'Centennial' and 'Jewel' plant was correlated highly with root dry matter accumulation of 'Centennial' (r = 0.82) and 'Jewel' (r = 0.72) plants (Tables 5,6, respectively). This is consistent with observations throughout the growing season, that is, the number of developing roots per plant is dependent on the number of nodes beneath the soil surface and apparently is not highly correlated with the amount of dry matter being transported into the roots of either 'Centennial' (r = 0.42) or 'Jewel' (r = 0.46) plants (Tables 5,6).

Very low correlation coefficients between the number of developing roots per plant and mean developing root diameter of each plant were noted for both cultivars, 'Centennial' (r = 0.14) and 'Jewel' (r = 0.17) (Tables 5,6). These results were not anticipated, however; this further substantiates the theory that the number of developing roots per plant is dependent on the number of nodes beneath the soil surface and is not related to transportation of dry matter into the roots.

High correlations were found to exist between stem dry weight and root dry matter accumulation of 'Centennial' (r = 0.74) and 'Jewel' (r = 0.80) plants (Tables 5,6). This suggests that plants having large

---

[2]Leaf area index and dry matter accumulation, developing root number and mean developing root diameter, developing root number and dry matter accumulation, and dry matter accumulation and stem dry weight were correlated with each other.

TABLE 5. Correlation Coefficients for Growth Parameters of 'Centennial' Sweet Potatoes

Growth Parameter	Developing Root Diameter ($\overline{X}$)	Dry Matter Accumulation	Stem Dry Weight
Leaf area index	---	.42	---
Developing root number	.14	.42	---
Developing root diameter ($\overline{X}$)	---	.82	---
Dry matter accumulation*	.82	---	.74

*Root dry matter accumulation.

TABLE 6. Correlation Coefficients for Growth Parameters of 'Jewel' Sweet Potatoes

Growth Parameter	Developing Root Diameter ($\overline{X}$)	Dry Matter Accumulation*	Stem Dry Weight
Leaf area index	---	.46	---
Developing root number	.17	.46	---
Developing root diameter ($\overline{X}$)	---	.72	---
Dry matter accumulation*	.72	---	.80

*Root dry matter accumulation.

stem weights accumulated the greatest amount of root dry matter. Commercial practices enhancing stem growth may in turn stimulate root dry matter accumulation.

In general, percentages of phosphorus (P), potassium (K), magnesium (Mg), and calcium (Ca) of 'Centennial' and 'Jewel' leaves declined throughout the growing season at Knoxville (Table 7). This was probably due to the dilution effect caused by foliage growth as the season progressed. Because of the high percentages of P, K, Mg, and Ca observed in the leaves apparently these soils were sufficiently fertile for sweet potato production.

TABLE 7. The Effect of Cultivar on Leaf Content of Phosphorus, Potassium, Magnesium and Calcium Throughout the Growing Season at Knoxville, Tennessee, 1980

Cultivar	Harvest (days from planting)	Concentration (%)			
		P	K	Mg	Ca
Centennial					
	30	.42	1.85	1.55	3.08
	60	.35	1.51	1.25	2.12
	90	.32	1.77	.57	1.41
	120	.29	1.69	.48	1.88
Jewel					
	30	.42	2.00	1.30	2.61
	60	.36	1.27	1.02	2.01
	90	.31	1.11	.87	1.90
	120	.31	1.61	.57	1.70

CHAPTER V

SUMMARY AND CONCLUSION

The objectives of this study were to (1) provide information on seasonal growth and growth characteristics of two sweet potato cultivars, 'Centennial' and 'Jewel,' (2) compare growth characteristics and marketable yield of vertically and horizontally orienting slips of these cultivars at planting, and (3) determine alternate methods for measuring leaf area of sweet potato plants.

Yields were influenced by transplant orientation. Vertically oriented 'Centennial' plants produced a higher percentage of U. S. number one roots and more marketable yield than horizontally oriented plants of the same cultivar. Plant orientation appeared to have no effect on grade or marketable yield of 'Jewel.'

Generally, horizontally oriented plants of 'Centennial' and vertically oriented plants of 'Jewel' maintained larger leaf area, more roots per plant, and higher root dry matter accumulation than the other orientations of the respective cultivars. Results from this study indicate that dry matter accumulation for both cultivars begins as early as 30 days from transplanting. One-third of the total root dry matter accumulated by 'Centennial' and 'Jewel' during the growing season occurred 60 days after transplanting. Generally, as stem growth rate for both cultivars increased, root growth rate slowed and as stem growth rate slowed root growth rate increased.

According to the growth study, horizontally oriented plants of both cultivars had larger developing roots than vertically oriented plants. No differences in plant survival for either root orientation of 'Centennial' or 'Jewel' was observed.

Relatively strong correlations were obtained between root dry matter accumulation and mean developing root diameter and between root dry matter and stem dry weight for each cultivar. Weaker correlations were found between the number of developing roots per plant and root dry matter accumulation and between number of developing roots and mean developing root diameter for both cultivars.

Methods based on the midvein length and fresh weight were found to correlate highly with the automatic area meter for determining leaf area.

In general, percentages of phosphorus (P), potassium (K), magnesium (Mg), and calcium (Ca) of 'Centennial' and 'Jewel' leaves declined as the season progressed at Knoxville.

Further research involving the effects of different root orientations on growth characteristics and yields of sweet potatoes is needed before recommendations for transplanting can be made.

LITERATURE CITED

LITERATURE CITED

1. Ammerman, G. R. 1979. Recommended guidelines to the sweet potato industry for meeting the needs of consumers. Southern Regional Agr. Expt. Stations Bul. 243.

2. Anderson, W. S. 1940. Sweet potato plant production in Mississippi. Mississippi Expt. Sta. Bul. 349.

3. Anderson, W. S. 1942. Fertilizers for starch sweet potatoes. Mississippi Expt. Sta. Bul. 367.

4. Anderson, W. S. and John W. Randolph. 1943. Sweet potato production. Mississippi Expt. Sta. Bul. 378.

5. Anonymous. 1954. Growing and selling sweet potatoes in Virginia. Virginia Joint Agr. Pub. 1.

6. Anonymous. 1981. Crop production: 1980 annual summary acreage yield production. U. S. Printing Office, Washington.

7. Beattie, J. H., Victor R. Boswell, and J. D. McCown. 1938. Sweet potato propagation and transplanting studies. U. S. Dept. Agr. Cir. 502.

8. Blanchar, R. W., George Rehm, and A. C. Caldwell. 1965. Sulfur in plant materials by digestion with nitric and perchloric acid. Soil Sci. Soc. Proc. 29: 71-72.

9. Brougham, R. W. 1956. Effect of intensity of defoliation on regrowth of pasture. Aust. J. Agr. Res. Rpt. 7.

10. Burton, B. T. 1959. The heinz handbook of nutrition. McGraw-Hill, New York.

11. Chen, L. H., Chih-chen Yang, and Max Allison. 1979. Better way to grow U. S. no. 1 sweet potato. Mississippi State Res. Rpt. 4 (15).

12. Clark, John C. 1975. Quality sweet potato production. University of Tennessee Agr. Ext. Pub. 420.

13. Cochran, H. L. 1943. Influence of time of planting and spacing on the yield of 'Porto Rico' and 'Triumph' sweet potatoes. Georgia Agr. Expt. Sta. Bul. 230.

14. Cooley, J. S. 1951. The sweet potato-its origin and primitive storage practices. Economic Botany 5: 378-386.

15. Crosby, Donald G. 1964. The organic constituents of food. III. Sweet potato. Food Science 29: 287-291.

16. Deonier, M. T. and L. J. Kushman. 1959. The effect of pre-sprouting and type of bed on the early production of sweet potato plants. Proc. Amer. Soc. Hort. Sci. 75: 557-560.

17. Edmond, J. B. and G. R. Ammerman. 1971. Sweet potatoes: production, processing, marketing. Avi, Wesport, Connecticut.

18. Edmond, J. B. and G. H. Dunkleburg. 1943. The influence of crowded bedding of roots on plant production of the 'Porto Rico' sweet potato. Proc. Amer. Soc. Hort. Sci. 43: 246-248.

19. Edmond, J. B., O. B. Garrison, R. E. Wright, Otis Woodard, C. E. Steinbauer, and M. T. Deonier. 1950. Cooperative studies of the effects of height of ridge, nitrogen supply and time of harvest on yield and flesh color of the 'Porto Rico' sweet potato. U. S. Dept. Agr. Cir. 832.

20. Ezell, B. D. and Maurguerite S. Wilcox. 1946. The ratio of carotene to carotenoid pigments in sweet potato varieties. Science 103: 193-194.

21. Hand, T. E. and L. L. Cockerham. 1921. The sweet potato. Macmillan, New York.

22. Hanway, J. J. and H. E. Thompson. 1967. How a soybean develops. Iowa State University Spec. Rpt. 53.

23. Hines, C. 1949. Effect of location on the yield, grade and quality of unit 1 'Porto Rico' sweet potato. M. S. Thesis, Louisiana State University, Baton Rouge, Louisiana.

24. Howard, F. D., J. H. MacGillivray, and M. Yomaguchi. 1962. Nutrient composition of fresh California-grown vegetables. California University Agri. Expt. Sta. Bul. 788.

25. Hughes, Harold D. and Darrel S. Metcalfe. 1972. Crop production. Macmillan, New York.

26. Jones, H. A. and T. J. Rosa. 1928. Truck crop plants. McGraw-Hill, New York.

27. Jones, L. G., R. J. Constantin and Travis P. Hernandez. 1979. The response of sweet potatoes to fertilizer phosphorus and potassium as related to levels of these elements in the soil. Louisiana State Bul. 722.

28. Kelly, William C. and Homer C. Thompson. 1959. Vegetable crops. McGraw-Hill, New York.

29. Kimbrough, W. D., A. E. Fieger and H. Lewis. 1946. Effect of date of planting and time of harvest on the carotene content of the 'Porto Rico' variety. Proc. Amer. Soc. Hort. Sci. 47: 400-402.

30. Leopold, Carl and Paul Krieldemann. 1975. Plant growth and development. McGraw-Hill, New York.

31. Loomis, W. E. 1933. Transplanting vegetable plants. Proc. Iowa Hort. Sci. 68: 221-224.

32. Lutz, J. M., M. T. Deonier and C. E. Steinbauer. 1946. Studies on possibilities and limitations of the seed piece method of planting sweet potatoes. Proc. Amer. Soc. Hort. Sci. 48: 443-448.

33. Martin, John H. and Warren H. Leonard. 1967. Principles of field crop production. Macmillan, New York.

34. Mitchell, Roger L. 1970. Crop growth and culture. Iowa State University Press, Ames, Iowa.

35. Nichiporovich, A. A. 1960. Photosynthesis and the theory of obtaining high crop yields. Field Crop Abst. 13: 169-175.

36. Noggle, G. Ray and George J. Fritz. 1976. Introductory plant physiology. Prentice-Hall, New Jersey.

37. Park, Joseph K., M. R. Powers and O. B. Garrison. 1953. Machinery for growing and harvesting sweet potatoes. South Carolina Expt. Sta. Bul. 404.

38. Paterson, D. R. and D. E. Speights. 1962. Some effects of irrigation and fertilizer on three varieties of sweet potatoes. Texas Agr. Expt. State Progress Rpt. 2254: 1-5.

39. Peterson, M. J., G. H. Aull, E. W. Krobel and J. C. Downing. 1946. Sweet potato production possibilities in South Carolina. South Carolina Agr. Expt. Sta. Bul. 364.

40. Pope, D. T. 1962. Fertilize plant beds. Amer. Vegetable Grower 10 (2): 16.

41. Price, J. C. C. 1930. The production and storage of sweet potato. Mississippi Agr. Expt. Sta. Bul. 279.

42. Radford, P. J. 1967. Growth analysis formulae-their use and abuse. Crop Science 7: 171-175.

43. Salisbury, Frank and Cleon Ross. 1969. Plant physiology. Wadsworth, California.

44. Scott, L. E. 1950. Potassium uptake by the sweet potato plant. Proc. Amer. Soc. Hort. Sci. 56: 248-252.

45. Scott, L. E. and John C. Bouwkamp. 1975. Effect of chronological age on composition and firmness of raw and processed sweet potatoes. HortScience 10: 165-168.

46. Taubenhaus, J. J. 1923. The culture and diseases of the sweet potato. E. P. Dutton, New York.

47. Tomkins, D. R. and R. D. Horton. 1974. Sprouting of sweet potatoes from root pieces as influenced by gibberellic acid or ethephon. HortScience 9 (4): 392-393.

48. Ware, George W. and J. P. McCollum. 1980. Producing vegetable crops. Interstate Printers and Publishers, Danville, Illinois.

49. Watson, D. J. 1952. The physiological basis of variation in yield. Adv. in Agron. 4: 101-144.

50. Webb, J. A. and P. R. Gorham. 1964. Translocation of photosynthetically assimilated C^{14} in straight-necked squash. Plant Physiol. 39: 663-672.

51. Woodard, O. 1932. Sweet potato culture in the coastal plain of Georgia. Georgia Coastal Plain Expt. Sta. Bul. 17.

VITA

David Wilson Monks was born in Lincoln County, Tennessee, on March 19, 1955. He attended Lincoln County High School and was graduated in 1973. He entered Middle Tennessee State University in the fall of 1973 and received the Bachelor of Science in 1977 with a major in Plant and Soil Science. He farmed for two years and entered the Graduate School of The University of Tennessee, Knoxville, in 1979. He was employed as a research assistant at The University of Tennessee, Knoxville, while completing the degree requirements and was graduated in 1981.

He is married to the former Lydia Denise Judkins of Smithville, Tennessee.