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I am submitting herewith a thesis written by McKinley Posely III entitled "Fertilizer Responses in Cowpea (Vigna unguiculata (L) Walp)." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial requirement for the requirements for the degree of Master of Science, with a major in Plant and Soil Science.

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FERTILIZER RESPONSES IN COWPEA (*Vigna unguiculata* (L) Walp).

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ABSTRACT

Evaluation of fertilizer rates, nutrient sources, time and method of application has been one of the major research areas to improve growth, development and yield of cowpeas. The first year of research consisted of three experiments evaluating, 1.) the effects of nitrogen (N) rates, N sources, time of N application, 2.) foliar N applications, and 3.) Phosphorus (P) and potassium (K) fertilization rate of southern peas. In the second year the experiments were expanded to include tests on cowpea responses to ratooning and starter fertilizer nutrient combinations.

Research was established on a Collins silt loam (Aquic Udifluvent, coarse-silty, mixed, acid, thermic) at the West Tennessee Experiment Station, Jackson, Tennessee. In 1990, the site was fall planted in wheat which was cut and removed prior to planting. The experimental designs varied with each experiment.

Some of the N applied in 1990 may have been immobilized by the decomposing wheat roots. This immobilization may have resulted in less N being available for uptake during the growing season requiring higher application rates for a response. In 1991, cool temperatures and excessive rains after planting may have resulted in cowpea yields being considerably lower than the 1990 yields. During the months of May and June, precipitation was 10.32 and 6.17 inches,

respectively, with an average temperature of 83^0 F.

The yield of cowpeas were not significantly affected by N source, N rate, or time of application. Yields varied slightly as a result of N source. Splitting the rate of applied N did not affect yields. Leaf N concentration was also unaffected by N rate, N source, and time of application. Both yields and leaf N concentrations varied due to year. Leaf N concentrations for the 60 lb/a rate was 2.83 percent N in 1990 compared to 4.24 percent in 1991. The highest mean yield was produced by the 30 lb/A N rate. Yields tended to be reduced with the 90 lb/A N rate.

In another test, cowpea yields were increased from soil applied and foliar applied N. In 1990, yields were increased with N rates up to 60 lb/A soil applied and 20 lb/A foliar applied. In 1991, yields were increased by soil applying 30 lb/A and foliar applying 10 lb/A of N.

Phosphorus and K fertilizer applications had no significant affect on cowpea yields when analyzed by year. Yields averaged across years showed that applying 120 lb/A of P_2O_5 reduced yields when compared with the 60 lb/A rate. Yields were unaffected by broadcasting K_2O. Phosphorus and K application rates had no significant effect on P, K, Ca, or Mg leaf concentrations. Applying 90 or 120 lb/A of P_2O_5 increased soil test levels from medium to high.

Cowpea yields for both the main crop and the ratoon crop were not affected by fertilizer treatments applied at planting. The main crop was planted on May 23 and harvested on August 5 for a total of 73 days from planting to harvest. The ratoon crop was harvested on September 27, 53 days after harvesting the main crop. The time interval between harvesting the main and ratoon crop was reduced 20 days for the ratooned crop. The ratooning process added an average of 1030 lb/A of shelled peas or an increase of 77 percent to the total yield.

Starter fertilizer treatments had no effect on yields. Yields ranged from 1077 to 1200 lb/A, with no marked differences between broadcast or the band (starter) treatment.

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CHAPTER I

INTRODUCTION

The "southernpea" (cowpea), Vigna unguiculata (L) Walp. is known by many common names. Some of these are "acre pea", "field pea", "crowder pea", "blackeyed pea", and "cowpea". American horticulturalists have introduced the name southernpea to refer to any type of cowpea being grown as a vegetable crop. Cowpeas are very popular and widely grown in the southern United States.

The cowpea originated in Africa and has been cultivated since ancient times (50). It is one of the most important sources of protein in underdeveloped countries and is grown throughout the tropics and subtropics. In countries where primitive cultural traditions and agricultural practices continue to exist, the seed, leaves, and shoots of cowpea provide a large portion of the protein in the human diet.

The cowpea has been used in the United States since the early 18th century and was once a very important agronomic and horticultural crop. Oakely (40) found evidence to support this in the writings of Presidents Washington and Jefferson. Morse (37) reported that the name "cowpea" appeared in the literature about 1798 and through the early years of the 20th century. The cowpea is an excellent forage, hay, and green manure crop. It is also well adapted to stressful conditions and has good nutritional qualities for livestock as well as humans.

Agronomic utilization of cowpeas over the years has declined, but it has remained an important horticultural crop in the southeastern and some southwestern states. These states have an extensive processing industry supplying cowpeas for consumption throughout the United States.

Fertilizer research has been a major area for improving growth, development, and yield of cowpeas, and increasing the relatively low net return per acre. Considerable research has been conducted evaluating cowpea response to applied fertilizers (26, 43, 58). Responses to fertilizers vary with soil type, climatic conditions, application rate, and to some extent materials (38, 41, 44).

Cowpeas can fix substantial amounts of atmospheric nitrogen (N) provided the appropriate rhizobia bacteria stimulates nodulation. Fernandez and Miller (9) report N application stimulated nodulation in soils low in residual N and inhibited nodulation in soils of moderate to high levels of residual N. Some researchers think that cowpea in association with the appropriate Rhizobium spp. bacteria can produce sufficient nitrogen for growth and development (1, 9, 11), while others, suggest that yields can be increased with N fertilizers applied at planting (7, 8, 18).

The research reported here was conducted at The University of Tennessee West Tennessee Experiment Station at

Jackson, in 1990 and 1991. The objectives of this research were to evaluate: 1. the effects of four N sources, their rates, and timing of applications on yield of cowpea; 2. the effects of foliar N and soil N rates on yield of cowpea; 3. the effects of phosphorus (P) and potassium (K) rates on plant uptake, and yield of cowpea, and their effects on soil extractable P and K; 4. the effect of applying starter nutrient combinations of N and P on the growth, development, and yield of cowpea; 5. the effect on yields from ratooning cowpeas, both separately and in conjunction with starter fertilizer, and foliar N.

CHAPTER II

LITERATURE REVIEW

I. HISTORY

The cowpea, Vigna unguiculata (L.) Walp has been cultivated since earliest times. Cowpea was cultivated in tropical regions of Africa, and was known in Sanskritic times in Egypt, Arabia, and India (50). It has been suggested by Wight (65) and Haplin (21) that cowpea originated in Asia, and from there spread into Arabia and Asia Minor. However, their contention can not be substantiated due to the absence of wild progenitors. Most writers accept Africa as the area of origin.

II. ADAPTATION

Cowpeas are a hot weather crop that is widely grown in the southern United States. They require about the same climatic conditions as corn, but require more degree days to mature. Although cowpeas grow best in the southern states, they are grown successfully in several north central states (32, 34).

Cowpeas are very sensitive to cold weather and may be severely injured by light frost. They grow best under humid conditions, and can withstand considerable drought (11, 29, 34). However, under severe drought conditions, seed and/or forage yields are reduced (32).

Cowpeas grow well on almost any well drained soil. However, they tolerate adverse conditions better than most other legumes. Cowpeas are deep rooted and have an optimum soil reaction ranging between pH 5.5 to 6.5 (11). In northern areas, the lighter, loamy soils are preferred for production because the plants mature earlier than when produced on heavier soils. Planting dates needs to be restricted until the danger of frost is past. When grown on soils high in fertility, the plants produce a heavy growth of vines but only a small yield of seed (6). Less vegetative growth and higher seed yields are obtained when grown on soils of low to moderate fertility (6, 29).

III. MORPHOLOGICAL DESCRIPTION

The cowpea belongs to the family Leguminoseae. It is an annual herbaceous legume, and resembles the common bean (Phaseolus sp.). It is an aggressive plant, which varies from viny, semi-viny, to bush-type, and is leafy with trifoliate leaves. It is an excellent contributor to soil nitrogen, making it an especially good crop for subsistence agriculture (56).

Growth habits of cowpea may be indeterminate or determinate depending on the cultivar (18, 57, 59). Cowpeas produce either white, yellow, or purple flowers which are borne in pairs on short racemes. These flowers show an arched or curved keel in the corolla as opposed to the coiled or twisted keel in *Phaseolus* sp. The flower has a lateral or horizontal stigma and is sometimes confused with *Dilochus* sp. which has a terminal stigma (47). Cowpeas are ordinarily self-pollinated. It is a rare occurrence when a natural cross occurs in the field (34). It produces two or more pods per peduncle that are 8 to 10 inches long, cylindrical, smooth, slightly curved, and may be yellow, purple, or brown when mature. The number of seeds per pod varies with the cultivar, ranging from 5 to 25 (32).

In contrast to the common bean, the cowpea is small seeded and many have an eye of color around the seed hilum. The seeds are bean shaped, but short in relation to their width. They can be either uniformly colored or multicolored depending on the cultivar. Some common solid colors are white, buff, brown, maroon, purple, and black, and depending on the type and cultivar, will usually have a second color ringed around the hilum. The multicolored seeds may be spotted, specked, or marbled. The seeds weigh about 60 pounds per bushel, with a pound containing from 1600 to 4400 seeds (29, 47).

The first cultivars were indeterminant with a continuous growth habit. The indeterminant cultivars produce seed until the plant is subject to one or more environmental conditions that end its growing cycle (6). Today, with the advent of mechanical harvesting, new cultivars have been developed that are determinant and bush-type in their growth habit. These cultivars mature more uniformly, generally having 85 to 95 percent of the pods maturing simultaneously (59).

There is a broad range in the characteristics of cowpea cultivars that are grown for horticultural use in the United States. The most valuable American cultivars grown for seed are classified as blackeye, crowder, cream, or field types. Each type produces a seed with a particular appearance and flavor, and appeals to a unique market segment. Two other types, yard-long beans, and cowpea cultivars developed for production of edible pods are grown to a limited extent in the United States (11, 34). A few cultivars exist within the Catjang group, recognized by erect small pods containing small spherical seeds crowded in the pod. The yard-long and the catjang cultivars produce less seed and/or forage than regular cultivars, so they are not of much commercial significance in the United States (34, 46).

IV. ECONOMIC IMPORTANCE

In 1981, world cowpea production was estimated at 2.27 million tons from 7.7 million hectares. Because cowpeas are a major subsistence crop in many African countries, two-thirds of the total world production occurs there. Nigeria and Niger produce 850,000 and 271,000 tons annually or 49.3 percent of the world crop. Brazil produces 26.4 percent or 600,000 tons of dry seed, making it the second highest worldwide producer (56).

Singh and Rachie (56) reported world production estimates to be conservative and vary widely. They estimate that cowpea production in Asia may be underestimated by a level of about 1 million hectares. They point out that half or 500,000 hectares of the Asian production is estimated to be cultivated in India alone in the form of dry seed, fodder, green pod, green manure and cover crops, while China produces approximately 1.4 million hectares of various dried peas (63).

Production estimates may also be low for Africa and countries in the Western hemisphere that traditionally included cowpea as a companion crop in peasant-farming systems. Accordingly, realistic production estimates may be about 2.5 million tons of dry seeds on approximately 9 million hectares (56).

The only developed country producing large amounts of cowpea is the United States, which produced about 80,000 tons in 1981 (11, 54). During the early part of the 20th century in the United States, the cowpea was an important agronomic crop. In 1917, an estimated 2.3 million hectares was in cowpea production in 22 states. Cowpea has never been popular as a grain crop, largely because of the difficulties of harvesting. As early as 1917, there was evidence of the decline of cowpea production. Oakley (40) stated "that with the growing popularity of the soybean and the rapid strides of the velvet bean, cowpeas are somewhat eclipsed, and the extension of their acreage appears to be unlikely".

Because it was an important crop in early America, the U. S. Department of Agriculture published annual statistics on cowpea culture until 1964, and some limited coverage was continued until 1967. After 1967 very little attention has been devoted to reporting annual cowpea statistics by the U. S. Department of Agriculture (11).

Between 1930 and 1939, cowpea production averaged 1.7 million hectares. In 1937, a high of 2.36 million hectares of cowpeas were planted, but production declined immediately thereafter. From 1957 through 1961, an average of 279,600 hectares of cowpea was produced for hay, seed, pasture, and green manure; average dry seed yields were about 480 kilograms per hectare (6, 11, 29). In 1965, cowpeas ranked thirty-sixth in hectarage (40,800) and thirtieth in value ($3,526,000) for field crops produced in the U. S. (29). Decreases in production being replaced in a large part by increases in acreage of soybean and lespedeza (6).

The low-input cultural practices used to grow cowpea hay and seed crops result in low yields. Low yields were a major factor in the decline in cowpea production (6, 11, 34, 40).

Today, cowpeas are used throughout the country as both a fresh green vegetable and a dry bean. It is a very popular vegetable in all the southern states, being consumed in the pod, as shelled green peas or as shelled dry peas in preference to other beans (10). Shelled-green cowpeas contain 9.4 percent protein, 0.5 percent fat, 23 percent carbohydrates, and 1.4 percent ash, with a food value of 620 calories per pound. The dried cowpeas contain 21.4 percent protein, 1.4 percent fat, 60.8 percent carbohydrates, 3.4 percent ash, and a food value of 1,590 calories per pound (29).

California and Texas are major producing states for the dry seed industry. Georgia is the leading processor of fresh peas, and Texas is the leading processor of imbibed "dry" peas. Because the U. S. Department of Agriculture no longer publishes data on cowpea production, accurate production statistics are not available. A survey conducted by Fery (10, 11) indicated that approximately 80,000 hectares of cowpea are grown in the U. S. each year, with estimated yields of about 43,150 metric tons of cowpea for human consumption. Acreage in Georgia, California, and Texas accounts for about 65 per cent of the total production (6, 10, 11, 29).

In 1968, cowpeas ranked third in total pounds of processed vegetables behind green beans and tomatoes in seven Southeastern states. Among these states Tennessee was the leader in blackeye peas produced for processing (14, 17).

From 1963 through 1968, Tennessee annual cowpea production averaged approximately 12,000 acres. In 1968, four plants in Tennessee processed 17.72 million pounds of blackeye peas, and three of these plants processed 7.64 million pounds of field peas, which includes blackeye, cream, and crowder peas. Tennessee's production was second to Georgia in cowpeas for processing and in total combined production of field and blackeye peas (17).

Recently cowpeas produced for the processing industry has come into even greater prominence in Tennessee. Because of their suitability for drying, freezing and canning, cowpeas have acquired additional recognition and development as an important vegetable crop (14). At present, the total area in cowpea production in Tennessee is estimated to be 9,091 acres. In 1992, Pictsweet Foods located in Bells, Tennessee processed 10,000,000 pounds of cowpeas. This represents $ 2,100,000 in income for Tennessee farmers.

V. CULTURE

Cowpeas are tolerant to drought and hot weather, and can be grown successfully under conditions that are entirely unsuitable for such table legumes as the common bean, *Phaseolus vulgaris* L. and the lima bean, *Phaseolus lunatas* L. (11, 29). Cowpeas are very susceptible to cold soils, and should not be planted in the spring until soil temperatures are above 68^0F (6, 11, 29, 32, 37). Production practices and equipment used for other table legumes may be successfully used for growing and harvesting cowpeas.

Between 1984 and 1988, California average yields for blackeye pea were 86 percent that of lima bean, and 106 percent that of common bean yield, totaling 98 percent of the state's dry bean industry. These figures indicate that under appropriate cultural and management practices, cowpea seed yields can equal those expected for the preferred *Phaseolus* species (11).

The rate, method, and time of planting varies, depending on the purpose for which the crop is to be grown. For seed production, cowpeas are commonly planted in 24 to 40 inch row spacings, with seeding rates ranging from 20 to 45 pounds per acre (29, 32). When row spacing is reduced to drill spacing (7-11 inches), seeding rates are increased to 60 to 120 pounds per acre. Spacing the seed two to three inches apart is recommended for forage production (6, 32). Stewart (57) found that green pod yield increased with decreasing row spacing from 42 to 18 inches for bunch-type cowpeas.

VI. NITROGEN FIXATION

Nitrogen (N) deficiency can restrict the expression of genetic yield potential of cowpea cultivars (9). Associated with N nutrition of cowpea is the presence or absence in the soil of a N fixing bacterium called *Rhizobium japonica*. Many soils have rhizobia bacteria that exist in a symbiotic relationship with legumes. The rhizobia bacteria fixes atmospheric N in the nodule and supplies it to the plant in exchange for glucose produced in photosynthesis. However, it is possible that the particular strain for the legume being grown may not be present in the soil (18).

To insure the presence of the correct bacteria, seeds are inoculated with suitable strains of *Rhizobium*. These N fixing bacteria infect the root hairs of cowpea, thereby producing nodules. It is in these nodules that N fixation occurs. Even though cowpea has the ability to symbiotically fix N, it has been a recommended practice to apply low N rates. Readily available soil N can be beneficial to the plant before fixation occurs (16, 18).

Ezedinma (8) noted that applying N at planting promoted growth and development of cowpeas in the period between the loss of the cotyledons after emergence and before the nodules became functional. Pandey (42) reported that leguminous crops have higher sulfur requirements than cereal crops. Sulfur stimulate nodule development, which contribute to the growth and yield of cowpeas. Sulfur increases the number of N fixing bacteria, as well as aids in conversion of fixed N to organic forms.

Investigations on the effect of N on nodulation have shown maximum symbiotic fixation to be associated with growth media deficient in N. High levels of N fertilizer have been found to inhibit nodulation. The magnitude of inhibition is influenced by plant species, host genotype, climate, *Rhizobium* strain, and N source (9).

VII. NITROGEN FERTILIZERS

Recently, agricultural use of nitrogen sources containing either ammonium N or become ammonium upon hydrolysis has generally increased. Matocha (35) stated that with the present tendency towards conserving energy and the increased efficiency of energy conversion in the manufacture of urea over certain other forms of dry N fertilizers, urea-based fertilizers will probably become increasingly important in the future. Problems associated with various N sources are leaching, ammonia volatilization, and denitrification. Erratic crop responses and frequent low recoveries of N have been related to these dilemmas. A promising approach to the problem involves control of dissolution and hydrolysis rate of urea (35).

In a study to evaluate various N sources and their interaction with different application methods in corn, Raun et al. (52) reported small differences among N sources. Urea-ammonium nitrate (UAN), urea, urea-ureaphosphate (UUP), and sulfur coated urea (SCU) were broadcast preplant, while anhydrous ammonia was applied preplant and sidedressed at the eight-leaf stage. Although UUP appeared to maximize total dry matter yield when compared with SCU, urea, and UAN over a three year period, Yields were unaffected by source.

The beneficial response of UUP was due to decreased ammonia losses because phosphoric acid maintains a lower soil pH following the enzymatic hydrolysis of urea by soil urease, and a lower soil pH lowers ammonium losses (52). Fox et al. (13) reported that surface applications of UUP tended to produce slightly greater N fertilizer efficiency than surface-banded urea.

Matocha (35) reported ammonium losses were reduced considerably from applying SCU to acid and calcareous soils when compared with urea and ammonium sulfate. Mughogbo et al. (38) reported no yield difference in calcium ammonium nitrate (CAN) and urea on cowpea. They found CAN tended to move deeper into the soil than urea-N, while urea-N remained near the surface and susceptible to volatilization N losses. Calcium ammonium nitrate has half its N in the nitrate form, which may be lost by leaching. Urea when surface applied to soils of low exchange capacity is subject to volatilization N losses, but less susceptible to leaching losses than CAN.

While factors such as soil type, temperature, and urease activity cannot be feasibly controlled in the field, others such as release rate of the N source, soil moisture, and cultural practices may be adjusted to fit many situations.

Fox and Hoffman (12) compared N source and N rate for no-till corn production. Their data indicated that plant N uptake and yields were lower from urea and UAN when compared to ammonium nitrate (AN) and ammonium sulfate (AS) when rainfall was less than 10 mm within two days after fertilizer applications. In conditions where rainfall was adequate, urea nitrogen was leached into the soil where it was fixed by organic matter and cation exchange capacity.

Howard and Tyler (24) reported that the method of applying urea containing N sources had a significant effect on N fertilizer availability. Injecting UAN and urea resulted in significantly higher yield, leaf N concentration, and N uptake when compared to broadcast and surface band application methods. Surface banding UAN at 168 and 224 kg/ha resulted in higher yields than urea or UUP. Differences in yield, leaf N concentration, and N uptake among the three urea containing N sources were not observed when broadcast applied. Broadcasting AN at 168 and 224 kg/ha resulted in higher yields than UAN, urea or UUP but, injecting the N sources resulted in higher yields when compared with broadcasting AN.

Balasubramanian and Singh (3) reported increases in corn and wheat yields with increased N rates, but N sources (urea, and CAN) and time of application did not have a significant effect on N use efficiency or yield.

Fox et al. (13) reported surfaced-banded AN, injected AN, and injected urea produced the same no-till corn yields and percentage of nitrogen uptake when averaged across application times. Generally, sidedressing N increased N efficiency of all sources, but the trend was more apparent for the urea-containing sources. They concluded this to probably be due to the high average number of adequate rainfall periods encountered after sidedressing over the three years of the experiment.

In a study evaluating cowpea response to N rate and seed inoculation, Halsey (18) reported a yield increase with N rates. Yields were higher with 18 lb/A of N applied when compared to no N. Rate of seed inoculum did not effect yield, but yields were lower from applying a combination of inoculum and a higher N rate of 36 lb/A. Among the nine N and inoculum level treatment combinations, the highest yield was obtained from the addition of 36 pounds of N with no inoculum added.

Awonaike et al. (1), reported soil N to be important during early vegetative growth, but that this importance declined significantly during the reproductive stages as N derived from the atmosphere (Ndfa) increased. Furthermore, whenever soil N is abundant, it is assimilated in preference to Ndfa, whereas Ndfa is the major N source once soil N becomes limiting. They concluded that Ndfa can contribute significantly toward the N nutrition of field grown cowpeas, serving also as an important source of N for pod development.

Fernandez and Miller (9) reported that applying fertilizer N to inoculated cowpeas did not increase N_2 fixation or seed yield. Therefore it may be more beneficial to inoculate cowpeas with a suitable inoculum rather than applying costly fertilizer N. They reported a linear increase in seed and biomass yield with increasing N levels in non-inoculated plants. Furthermore, N fixation potential did not affect seed yield of cowpea cultivars; however, vegetative matter was greater in high-fixing than in low-fixing cultivars. Although differences in N_2 fixation potential among cowpea cultivars exist, increases in seed yield might not be realized without an increase in N sink potential.

VIII. FOLIAR NITROGEN FERTILIZER

Foliar fertilization has been utilized for some time to apply N and micronutrients to fruit, vegetable, and grain crops where soil conditions limit efficient utilization of soil applied micronutrients. Foliar application of major nutrients can not replace soil application and is not a substitute for a good fertility program. If all other factors are optimum, foliar fertilization can result in an increase in yields (19).

Hanway (20) had a particular interest in foliar fertilization and evaluated its potential for soybeans during the seed-filling period. The research indicated that as soybeans grow the content of N, phosphorus (P), potassium (K), and sulfur (S) in the vegetative parts of the plant increases until after seed initiation. At seed initiation, growth of the root system stops, resulting in a slowing or stopping of uptake of some nutrients. When this occurs, the nutrients contained in the leaves and stems start to translocate from the vegetative to the reproductive parts of the plants. The depletion of nutrients from the leaves results in decreased photosynthesis, the leaves turn yellow and fall off the plant. Hoeft (22) stated that foliar applying nutrients at this time, would delay senescence and increase yields.

Garcia and Hanway (16) reported from two years of field experiments, that soybean yields were increased by foliar applications of a N, P, K, and S solution during the seed filling period. The results substantiate the hypothesis that nutrient uptake from soil was inadequate to supply the needs of the plant and applying foliar nutrients at this time would avoid the normally observed depletion of N, P, K, and

S from leaves during the seed-filling period.

Hanway (20) reports that nutrient depletion seems to occur irrespective of the availability of these nutrients in the soil, and during the seed-filling period probably results from inadequate carbohydrate nutrition of the roots which provides the energy to take up sufficient nutrients. Foliar spraying N, P, K, and S during this period, minimizes nutrient depletion of the leaves, so photosynthesis will be maintained at a higher level resulting in increased seed yields.

Many researchers (16, 19, 20, 22, 49) suggest that these four nutrients N, P, K, and S, normally are depleted in the leaves, and that foliar spraying is an effective method of application in the proportions found in the seeds. They suggest that this explains why foliar sprays that supplied only one or two of these elements during the seed-filling period were not effective. Recent research on soybeans (16, 19, 20, 31) indicates that two to four foliar applications during the seed-fill period are most effective. Furthermore, more frequent applications with lesser amounts are not as effective, and neither are applications only at the beginning or at the end of the seed filling period as effective as applications spaced throughout the period. Excess rates at any one spraying may result in leaf burn and should be avoided.

Ham (19) found that when conventional fertilizers are used in foliar solutions they may decrease soybean yields, indicating the importance of using the proper source of nutrients. In another study, Ham (19) found yields of soybean were increased by treatment with Folian II. Ham (19) also found that by adding P, K, and S from the same sources used in Folian II, and changing the N source to calcium nitrate, ammonium sulfate or ammonium chloride, yields were reduced very severely due to burning. Adding N only as a foliar or soil treatment did not increase yields.

The recommended rate of application per acre for soybeans is up to 20 pounds of N, 2 pounds of P, 6 pounds of K, and 1 pound of S. Urea supplies the N: some of the K and all the S come from potassium sulfate; and the P and additional K comes from potassium polyphosphate. All four nutrients must be in solution. Omitting any one of the nutrients decreases yield response (22, 49).

While conducting research that compared Folian II with conventional fertilizers that are cheaper and more available, Poole et al. (49) found that soybean yields were not significantly increased across all locations and varieties. Folian II increased the yields of two varieties at one location and one variety at a second location. Substituting UAN (28 % N) in place of urea resulted in severe leaf burn and reduced yields.

Lawrence et al. (31) compared 5 experimental foliar fertilizer solutions, Folian II, TVA, Pennzoil, Bayfolan, and Leffingwell. Their data indicated that yields were unaffected by any of the 5 foliar treatments.

IX. PHOSPHORUS AND POTASSIUM FERTILIZER

Phosphorus, although not required in large quantities, is critical to cowpea production because of its multiple effects on plant nutrition. Absorption of P occurs primarily at the end of the growing period and is mainly transported to the seed. Phosphorus increases nodulation as well as seed yield, and influences the contents of other nutrients in the leaves and seeds (50).

Rachie and Roberts (50) recommend 100-200 kg/ha of superphosphate to stimulate vegetative growth on soils low in extractable phosphorus. Singh and Rachie (56) state that other nutrients (K, S, Ca) are of little importance in cowpea culture and need only to be supplied to deficient soils.

Subrahmanyam and Dixit (60) reported a yield increase in cowpeas from P soil applied to a sandy clay loam over foliar applications of phosphoric acid. They found that soil applications also increased plant height. The highest grain yield resulted with soil application of 20 kg/ha of phosphorus in comparison with higher levels (40 and 60 kg/ha) of soil applied phosphorus.

Kalra and Khokhar (28) observed that the percentage of

P uptake in cowpea fodder was generally depressed with increased levels of N, while K applications did not affect green fodder yield but did increase the nutritive value of the fodder. Adequate amounts of phosphorus in soils favor rapid plant growth and early fruiting or maturity, and improve the quality of vegetation (34).

Paterson and Blackhurst (43) reported a highly significant increase in the yield of cowpea on a P deficient sandy loam with moderate extractable soil K, but they observed no significant effects when extractable soil P and K were high. They also stated that they could reduce the maturity period by increasing the levels of phosphoric acid to 80 lb/a and keeping nitrogen applications at 40 lb/a. This was important in that area of Texas where the research was conducted because there is usually more moisture available early in the growing season.

Stewart (59) evaluated row spacings of cowpea on a sandy loam that tested high in extractable P and K. His results showed a trend towards a reduction in yield when the applied K exceeded the amount of applied P. Martin et al. (34) stated that generally, adequate soil K improved the quality of plants, insured greater efficiency in photosynthesis, increased resistance to certain diseases, helped to balance an oversupply of N, and aided plants to utilize soil moisture more advantageously. In corn crops potassium was instrumental in influencing the development of well-filled kernels, and is a chief component in stem strength of most plants. Potassium encourages growth in leguminous crops, aids in chlorophyll formation, and is particularly beneficial in the production of starch- or sugar-forming crops.

Rachie and Roberts (50) stated that K is transported mainly to the stem in early growth and later to the seeds. They reported field response to K by cowpeas has been low in Africa although K applications of 40 kg/ha have increased nodulation of cowpeas in the West African state of Nigeria. While conducting fertilizer trials on cowpea in Western Nigeria, Osiname (41) reported that while P applications increased yields at one of two locations, K application did not affect yields.

Peck et al. (45) reported that when available soil K is high, K fertilization of snap beans may decrease yields, while applying P to a high P soil is likely to increase yields. They tested two K sources at two application rates on snap bean at 17 locations in New York. Results indicated that on low extractable K soils applying 33 lb/A of K increased yields 26 percent. Yields were unaffected by applying K to a medium testing soils, and yields were decreased 7 percent by applying K to a high testing soils. The response to the higher rate (66 pounds) of K/A was variable and was apparently related to factors such as distance of fertilizer band from seed, available soil water, soil P and soil K level, and variety.

Worley et al. (66) applied 63 lb/A of K to a medium testing soil and reduced cowpea yields. They recommended that the level of soil applied K not exceed 42 lb/A. Stewart and Reed (58) reported plant growth of cowpea at early bloom stage was not significantly affected by applied N and K, but highly significant growth increases resulted from increasing rates of P applications up to 100 lb/A. There was no additional yield increase when P was increased from 100 to 200 lb/A. Potassium did not increase yields in the first year of the experiment but did in the second year. This was a result of the soil K level going from medium to low in the second year.

Howard et al. (26) found that K_2O applications did not affect green pod or total shelled-pea yields, and applications of 120 lb/A of P_2O_5 hastened maturity in cowpeas. Significant treatment differences found in the yield of dry shelled peas were due to the high P rate. Reducing P rates allowed for a longer period of harvesting green pods (43).

X. RATOONING

Plunknett et al. (48) define ratoon cropping as: 1. more than one harvest from a single planting; 2. regrowth from basal buds on the stem or crown situated at ground level; 3. harvesting of most or all of the aerial portion of the plant; and 4. harvesting of selected portions of the plant, e.g., fruit, leaves, portions of stems or combinations of these.

The first harvest is usually called the plant crop because it was derived from planted seed, and each succeeding harvest is designated first ratoon, second ratoon, etc. Ratooning has traditionally been a cropping technique for sugarcane, pineapple, and banana and more recently to grain and forage sorghum, cotton, rice, ramie, patchouli, some vegetables, and even trees. Coppicing (ratooning) of timber is a common practice in the forestry industry (48).

The major advantages of ratooning are: 1.) reduction in the cost of cultivation; 2.) saving in seed, labor, fertilizer, and time; 3.) contribution towards the increased food and fodder production; 4.) higher monetary returns per unit area; and 5.) better utilization of the land and other resources of the farmer (30).

Ratooning is a common practice in sugarcane culture, where the initial seeding may be ratooned 9 times. In India, the practice of ratooning is popular in the production of hybrid sorghums. Unlike sugarcane, hybrid sorghum can be ratooned only once. In India sorghum is a major staple food and fodder crop, therefore taking a successful ratoon crop would go a long way in shortening the time required for achieving self-sufficiency (30).

In countries like Pakistan, the regular supply of fresh and green fodder is essential for animals supporting agriculture. Farmers in northern India also give preference to fodder over grain from sorghum. To satisfy this demand the traditional agronomic practices for sorghum cultivation had to be adjusted to provide green fodder during scarcity periods (dry summer months), and dry fodder as well as good grain yields at the termination of the rainy season (33).

While conducting tests with local and hybrid sorghum varieties, Mahendra and Kaushik (33) observed that both varieties took longer periods to come to ear emergence during summer months (74-80 days), as opposed to about 55-65 days during the rainy season. Immediately after harvesting, cultivars were allowed to ratoon, and a direct seeding was made to compare with the ratooning cultivars. Growth of the ratooned crop was vigorous and was 80 and 85 days to maturity as compared to 100 and 110 days for the planted crop. The ratoon crop also gave significantly higher grain and fodder yields. Sarma et al. (55) conducted yield tests on short season hybrid sorghum cultivars in comparison to long season local cultivars of sorghum in an attempt to raise two crops in a single year. Their results indicated that the yield potential of the 2 hybrids they compared was increased by ratooning.

Balasubramanian et al. (2) reported that ratooning to be a varietal character in rice. They reported that when compared to the planted crop the plant height in the ratoon crop was lower. N applications increased the yield of grain as well as straw in the ratoon crop, but maximum response was not obtained even at the 120 kg/ha N rate. The ratoon crop of all four varieties reached maturity before the planted crop.

In the Tamil Nadu region of India, a type of ratooning with cowpea has been a common practice for years. This ratooning utilizes the leaves from the plant, which are plucked four or five times as a vegetable, then regrowth is encouraged and the grain is harvested (64).

Researchers (64) at Tamil Nadu University have designed and introduced a different form of ratoon cropping that appears to be a breakthrough in the production of cowpea for this region. The normal ratooning practice is followed, except that after the dried pods were harvested at 71 days after sowing, the crop is irrigated to induce fresh regrowth and bloom. By the 80th day after the sowing, nearly 50 percent of flowering was completed. Green pods were harvested at the 88th, 89th, and 90th day after sowing, under the vegetable ratoon treatment, and a grain crop was harvested on the 96th day after sowing in the case of the grain ratoon treatment.

The ratoon yield increased productivity over the single crop yield. The mean yield of ratooned grain was 963.2 kg/ha which was 77.3 percent of the main crop yield, thus increasing productivity to 177.3 percent. The mean yield of pods as a vegetable in the ratooned crop was 2165.5 kg/ha. The highest net return was for grain plus vegetable ratoon rather than grain plus grain ratoon. With the new ratooning practice, Venktaraman and co-workers (64) illustrated that within 90 days it is possible to get a grain plus vegetable ratoon crop instead of the traditional single harvest from the main crop after 71 days. The end result of the new ratoon systems was a higher net income, which was attributed to savings in the cost of seed, fertilizer and other cultural operations.

In a preliminary experiment, Paterson and Blackhurst (44) found that after the first harvest of 'Extra Early Blackeye' cowpea more than half the crop appeared to be left on the vines. However, because of a rapid defoliation and desiccation of the pea vines, the yield at the second harvest was only 1,280 pounds as compared with 3,024 pounds from the first harvest. In other experiments they irrigated with 3 inches of water after the first harvest, the ratooning practice resulted in an 87 percent increase in yield.

While conducting ratooning experiments with sorghum, Touchton and Martin (62) reported a total grain yield of 9,847 kg/ha from the planted and ratooned crop. They suggested that 67 kg/ha of N was sufficient for ratooned grain sorghum, and that the applied N would be economical if a well managed insecticide program was followed.

XI. STARTER FERTILIZER NUTRIENT COMBINATIONS

The need for starter fertilizers with spring planted grain crops is a widely debated subject. Most everyone agrees that starters improve early plant growth in cool soils, but there is some doubt as to whether or not the early plant vigor translates into higher grain yields (61).

Responses to starter fertilizers will most likely occur when seeds are planted in cool soils, and when soils test low-to-medium in extractable phosphorus. Recently, there has been a trend in the southeastern states to minimize tillage and to plant at the earliest possible date. Usually, both of these practices mean that soils will be cooler during the initial periods of growth. Starter fertilizers give plants an advantage in cold, wet soils (61).

Since they are generally applied in a band near the seed or in the furrow, starter fertilizers maximize fertilizer efficiency in a time when overall farm operating cost are escalating. In northern growing areas soil P and/or N levels may be deficient early in the season. Under these conditions there may be a response to starter P and K, but a slightly lower response to N, especially, on heavy soils that are subject to wet springs (34). When N and P are applied together in a starter, the amount of P uptake by the plant is significantly increased (39). Nitrogen enhances P uptake and should be considered as an essential component in a starter program.

Touchton and Hargrove (61) tested starter fertilizers in grain sorghum and reported a general overall yield increase with starter fertilizers, however the greatest response to starter fertilizer was in the no tillage system. Howard and Tyler (23) reported that surface applied P and K had no affect in no-till corn on a low P and medium K testing soil. They found that in-furrow applications of N-P-K combinations increased yields in each of three years; but, no one treatment combination produced the highest yield every year. In-furrow applications had no significant effect on plant populations or early plant growth.

Rickerl et al. (54) showed starter fertilizers improved cotton seedling survival and yield when cotton was produced in leguminous mulches. They found that N and K combinations promoted plant growth with populations at harvest being 41% greater than those found in the no-starter treatment, and yields that were 27% greater than non-starter yields. Applications of P starters did not consistently improve cotton populations but, starter treatments generally resulted in higher yields.

Howard and Hoskinson (25) reported no-till cotton yields were higher with starter (band) applications of 15-

15-0 or 30-0-0 than with a 60-30-30 broadcast application. Applying fertilizer in a broadcast plus band combination significantly increased yields when compared to yields from broadcasting. Banding 15-15-0 produced the highest average yield over 5 years. Increasing the band above 15-15-0 lb/A did not increase yields when compared to yields from broadcasting 60-30-30.

Funderburg (15) evaluated starters on cotton at 18 Mississippi locations. Results indicated positive yield responses at 17 of the locations, with yield differences being significant for 13 of the 17 locations. Plant mapping indicated that plants treated with starter fertilizer initiated fruiting one node lower than untreated plants. In some cases starters reduced time to maturity, while in other cases, no difference were noted.

Fertilizer banded in the seed zone has greater efficiency than an equal amount of broadcasted material, because more of the fertilizer placed in this manner is taken up by the plant. Broadcast fertilizer requires two or three times the amount needed for similar responses as that of the band application method (39, 51, 61).

CHAPTER III

MATERIALS AND METHODS

Research was conducted during the summer months of 1990 and 1991 at the University of Tennessee West Tennessee Experiment Station at Jackson, Tennessee. Three experiments were conducted in 1990. These tests were: 1.) nitrogen (N) source fertilizers; 2.) foliar N applications; 3.) P and K fertilizer. The number of experiments were expanded in 1991 to include tests evaluating the ratooning of cowpeas, and their response to starter fertilizer nutrient combinations.

The experiments were established on a Collins silt loam (Aquic Udifluvent, coarse-silty, mixed, acid, thermic) in 1990. The site had been fall planted to wheat which was removed prior to planting. The experimental designs varied with experiments and are outlined below.

The cowpea cultivar 'Coronet' was planted in 1990 and 1991. In both years, 'Coronet' was planted on May 24 in 30 inch rows using a four row "John Deere Max-Emerge 2" planter. Individual plots were 10 feet wide by 30 feet long. Phosphorus and K rates of 30 lb/A were applied in all plots except those in the P and K experiment using concentrated superphosphate (0-46-0) and muriate of potash (0-0-60) . Nitrogen was broadcast at 30 lb/A using ammonium nitrate immediately after planting to all plots except the N source test.

On June 5, 1990 and June 3, 1991, plots were sprayed with 2 quarts/A of carbaryl for insect control. On July 19, 1991, esfenbalerate was applied at 9.6 fluid ounces per acre for control of Cowpea Curculio during the pod fill period. During June of both years, plots were cultivated twice to control redroot pigweed (Amaranthus retroflexus) and johnson grass (Sorghum halepense).

Plots were irrigated during periods of low rainfall. In 1990 the plots were irrigated on July 2nd and July 29th with 1.0 inch of water. In 1991 the N sources, foliar, and P and K tests were irrigated on July 16 with 1.4 inches of water. The ratoon and starter tests were irrigated 4 times during the last two weeks of July for a total of 3.5 inches of water. The ratoon plots were irrigated another 5 times between August 5th through August 23rd for a total of 3.25 inches of water after harvest of the initial crop.

I. TESTS

TEST 1. N Sources, Rates, and Time of Application Experiment

Research was established to evaluate: 1.) ammonium sulfate, ammonium nitrate, calcium nitrate, and urea as N sources for cowpea; 2.) N rates of 0, 30, 60, and 90 lb/A on cowpea; and, 3.) time of N application, with N applied at planting or split with 1/2 applied at planting and 1/2 at flowering, on cowpea.

The experimental design was a randomized complete block with a factorial arrangement of treatments. Treatments were replicated five times.

TEST 2. Foliar N Fertilizer Experiment

Research was established to evaluate: 1.) soil applied N rates of 0, 30, 60, or 90 lb/A. and, 2.) foliar N rates of 0, 10, 20, and 30 lb/A on cowpeas.

The experimental design was a randomized complete block with a split plot arrangement of treatments. Main plot treatments were soil applied N rates of 0, 30, 60, and 90 lb/A N rates. Sub-plot treatments were foliar N rates of 0, 10, 20, and 30 lb/A. Treatments were replicated five times.

Nitrogen rates were broadcast immediately after planting using ammonium nitrate. Foliar N was applied at 10 lb/A per application using urea. Applications were initiated at early flowering and continued on weekly intervals until required treatment rates were applied. However in 1990, after the second, leaf burn was observed and the rate per application was reduced to 5 lb/A requiring a fourth application to reach the 30 lb/A treatment rate.

TEST 3. P and K Fertilizer Experiment

Research was established to evaluate: 1.) P and K rates on cowpeas; 2.) P and K rates on soil extractable P and K; and, 3.) P and K rates on plant tissue P and K concentrations.

The experimental design was a randomized complete block with treatments replicated five times. Phosphorus and K fertilizer rates were broadcast at 0, 30, 60, 90, or 120 lb/A for a total of ten treatments. Fertilizer sources were concentrated superphosphate (0-46-0) and muriate of potash (0-0-60). Nitrogen was broadcast to all plots at 30 lb/A using ammonium nitrate.

TEST 4. Ratooning Experiment

Research was established to evaluate: 1.) ratooning of cowpeas; and, 2.) starter nutrient combinations, and foliar N applications on the growth and development of cowpeas and ratooned cowpeas.

The experimental design was a randomized complete block with treatments replicated five times. Treatments included N-P_2O_5 nutrient combinations applied in a 2" x 2" band, broadcast N-P-K rates, and foliar N applications. Phosphorus and K were applied either broadcast or as a combination of broadcast plus band application. The rate of P_2O_5 and K_2O

applied totaled 30 lb/A. Nitrogen rates of 60 or 90 lb/A were applied broadcast, a combination of broadcast plus band, or a combination of broadcast, band and foliar. The foliar applications were applied in three 10 lb/A N increments using urea. Foliar applications were initiated at flowering and applied on a weekly interval for three weeks. Broadcast N, P, and K materials were applied using ammonium nitrate (34-0-0), concentrated superphosphate (0-46-0) and muriate of potash (0-0-60). Starters were applied using liquid fertilizers 32-0-0 and 11-37-0.

Cowpeas were harvested on August 5 and again on September 27. Plots were not fertilized after the first harvest and no effort was made to control weeds.

TEST 5. Starter Fertilizer Nutrient Combinations Experiment

Research was established to evaluate: 1.) the effect of starter fertilizers on growth and development of cowpeas; and, 2.) the effect of N and P_2O_5 combinations as starters on growth and development of cowpeas.

The experimental design was a randomized complete block with treatments replicated five times. Total N-P_2O_5-K_2O rates applied per plot were 60-30-30 lb/A, respectively. Nitrogen and P_2O_5 starters applied as a 2 x 2 band were 15-0-0, 15-15-0, 15-30-0, 30-0-0, and 30-30-0 lb/A. Starters were applied using liquid fertilizers 32-0-0 and 11-37-0.

II.ANALYSES

Collection of Field Data

Leaf tissue was collected at flowering time to evaluate the treatment effect on leaf concentrations of N, P, K, Calcium (Ca), and Magnesium (Mg). The sampling procedure consisted of taking the top trifoliate leaf tissue from eight to ten randomly selected plants of the two center rows. Plant samples were dried in forced-air ovens at 68^{0}C, ground to pass a 40-mesh screen and stored for analysis.

Cowpeas were harvested 4 days after applying sodium chlorate as a desiccant at a rate of 1.5 gal per acre. In 1990, plots were harvested on August 10th, and in 1991 plots were harvested on August 5th. The two center rows of each plot were harvested with an Allis Chalmers Gleaner combine. Grain weight and moisture content were recorded. Grain yields were determined by adjusting field plot weights to a 20 percent moisture level.

Soil samples were collected in 1991 before fertilizer was applied and the results are shown in Table 1. After harvest in 1991, soil samples were taken to a depth of 6 inches to evaluate the effect of P and K fertilization rate on extractable P and K levels. Extractable P and K rates were evaluated by the Mehlich I extraction method (36).

Laboratory Analyses

Leaf samples from the N tests were analyzed for N content using the total automatic N determination method utilizing the Carlo Erba N Analyzer 1500 (5).

Leaf concentration of K, Ca, Mg, and P were evaluated following the sulfuric acid (H_2SO_4) and hydrogen peroxide (H_2O_2) digestive procedure (Appendix A). Mineral concentrations of the digestate were measured using the 'Inductively Coupled Argon Plasma Spectrometry' (ICAP) (27).

TABLE 1. Soil test results for soil pH, and available phosphorus and potassium before fertilization of cowpea plots at Jackson, Tennessee, 1991.

Cowpea Tests	pH	P	K
		-----(lb/A)-----	
N source	6.4	36 H[a]	120 M
Foliar	6.5	24 M	110 M
P and K	6.4	30 M	100 M
Starter	6.5	28 M	100 M

[a]Ratings: The letter following the level of the respective nutrient indicates relative availability of nutrients to plants in accordance with The University of Tennessee Agricultural Extension Service soil testing laboratory. (L)= Low; (M) = Medium; (H) = High.

Statistical Analyses

Statistical Analysis System (SAS) procedures were used to analyze the data (53). Analysis of variance (ANOVA), and

Fisher's least significant difference (LSD) were used to separate significant treatment means at the 5% level of probability. Because some plots in each replication of the ratoon and starter tests were damaged by irrigation equipment, they were analyzed using the General Linear Mixed Model (GLMM) program (4).

CHAPTER IV

RESULTS AND DISCUSSION

I. NITROGEN FERTILIZERS

Cowpea yields were not significantly affected by N source, N rate, or time (split) of N application (TABLES 2 and 3, See Appendices D, E, F, and G for Anova tables). Fox et al. (13), Howard and Tyler (24), and Raun et al. (52) reported similar findings when N sources were evaluated in no-till corn. Although irrigation was applied twice, splitting the rate of applied N did not increase yields. In most cases, yield responses from applying a given N source after planting were greater in comparison with yield responses obtained from splitting the N application into 1/2 after planting and 1/2 at flowering (TABLE 2).

Raun et al. (52) reported a high potential for immobilization of N when applied in minimum tillage systems. Some of the N applied in 1990 may have been immobilized by the decomposing wheat roots. This immobilization may have resulted in less N being available for uptake during the growing season and appears to have increased yields in 1990. Howard and Tyler (24) found reduced N availability in no-till corn due to N immobilization by surface residues when urea-containing N sources were broadcasted.

TABLE 2. Effect of N source and time of application on yield of green shelled cowpeas at Jackson, Tennessee, 1990 and 1991.

N Source	Time of Application	Mean Yield 1990	Mean Yield 1991
		----(lb/A)----	
Calcium Nitrate	(1) planting	1445	486
	(2) flowering	1378	548
Ammonium Nitrate	(1) planting	1342	516
	(2) flowering	1371	504
Urea	(1) planting	1468	488
	(2) flowering	1426	562
Ammonium Sulfate	(1) planting	1499	520
	(2) flowering	1432	481
Contrast[a]: planting vs flowering		0.37	0.48

[a](*) Probable F is significant at Alpha = 0.05.

TABLE 3. Effect of N rate and N source on yield of green shelled cowpeas at Jackson, Tennessee, 1990 and 1991.

N Source	Rate	Mean Yield 1990	Mean Yield 1991
		---------(lb/A)---------	
Check	0	1350	483
1. Calcium Nitrate	30	1516	476
	60	1374	506
	90	----	477
2. Ammoniun Nitrate	30	1266	560
	60	1417	496
	90	----	494
3. Urea	30	1389	578
	60	1546	458
	90	----	428
4. Ammonium Sulfate	30	1552	563
	60	1446	551
	90	----	446
Effect of N Rate			
	0	1350	483
	30	1422	544
	60	1418	513
	90	----	461
LSD		NS	NS
Contrasts[a]:			
Rate			
30 vs 60		0.82	0.30
30 vs 90		----	0.04*
60 vs 90		----	0.29
Source			
1 vs 2		0.29	0.51
1 vs 3		0.81	0.97
1 vs 4		0.57	0.46
2 vs 3		0.19	0.53
2 vs 4		0.11	0.93
3 vs 4		0.74	0.48

[a] (*) Probable F is significant at Alpha = 0.05.

In 1990 and 1991, no significant differences were found in leaf N content as a result of N rate, N source, and time of application. Leaf N concentrations for the 60 lb/a rate was 2.83 percent in 1990 compared to 4.24 percent in 1991 (TABLE 4).

In 1991, cool temperatures and excessive rains after planting may have reduced cowpea yields when compared with yields in 1990. During the months of May and June, precipitation was 10.32 and 6.17 inches, respectively, with average temperature of 83^0 F (Appendices B and C). The highest mean yield was produced by the 30 lb/A N rate. Applying 30 lb/A of N as calcium nitrate resulted in the lowest mean yield. Splitting the 60 lb/A N rate did not increase yields in either 1990, or 1991 (TABLE 2). Although not significant, the 90 lb/A N rate reduced yields when compared with the 60 lb/A N rate. The 30 lb/A N rate resulted in higher yields when contrasted with applying 90 lb/A of N (TABLE 3).

II. FOLIAR NITROGEN FERTILIZER

Cowpea yields were increased by both soil and foliar applied N. In 1990 and 1991 results showed a significant difference in yield from treatment effects for both soil applied and foliar applied N (Appendix H). These findings are similar to those of Poole et al. (49). They reported

TABLE 4. Effect of N rate, N source, and time of application on leaf N concentration of cowpeas at Jackson, Tennessee, 1990 and 1991.

Treatment	Leaf N Concentration 1990	1991
N Rate: (lb/A)	-----(% N)-----	
0	2.83	4.32
30	2.77	4.24
60	2.83	4.24
90		4.35
LSD (0.05)	NS	NS
N Source:		
Calcium Nitrate	2.76	4.24
Ammonium Nitrate	2.85	4.19
Urea	2.76	4.26
Ammonium Sulfate	2.83	4.27
LSD (0.05)	NS	NS
Time of Application:		
Planting	2.89	4.25
Split	2.71	4.30
LSD (0.05)	NS	NS

that foliar fertilization has the potential for increasing soybean seed yields, however, the yields are not consistent nor dependable.

The 1990 yields were increased by applying 60 lb/A of N as ammonium nitrate with foliar applications of 20 lb/A of N (TABLE 5). In 1991, yields were increased by applying 30 lb/A N at planting plus foliar applying 10 lb/A N.

Differences in yield responses over the two years may have been due to immobilization of N (12, 52). Decomposing wheat roots may have immobilized some of the soil applied nitrogen in 1990, and this was not the case in 1991.

In 1991, leaf N concentrations were unaffected by soil applied N rates (TABLE 6). Although not significantly different, leaf N concentrations were considerably higher than the 1990 leaf N concentrations. This effect indicates uninhibited nitrogen uptake in 1991.

III. PHOSPHORUS AND POTASSIUM FERTILIZER

Yields were unaffected by P or K rates for either year (TABLE 7 and Appendix I). However, when averaged over two years the data indicates that applications of 120 lb/A of P_2O_5 reduced yields. Although not significantly different, mean yields from applying 90 lb/A of P_2O_5 were lower than those from 60 lb/A rate. This observation indicates that P fertilizer applications to soils testing medium in

TABLE 5. Effect of soil applied N and foliar N on yield of green shelled cowpeas at Jackson, Tennessee, 1990 and 1991.

Soil N	Foliar N	Mean yield 1990	Mean yield 1991
(lb/A)			
0	0	1244	589
0	10	1281	618
0	20	1281	653
0	30	1282	644
30	0	1217	584
30	10	1132	801
30	20	1339	708
30	30	1285	728
60	0	1446	672
60	10	1469	766
60	20	1601	710
60	30	1643	680
90	0		668
90	10		694
90	20		723
90	30		668
Contrast[a]:			
Preplant N			
0vs30,60,90		-----	0.001*
0vs30,60		0.000*	0.002*
0vs30		0.490	0.003*
0vs60		0.000*	0.002*
0vs90		-----	0.013*
30vs60		0.000*	0.941
30vs90		-----	0.492
60vs90		-----	0.447
Foliar N			
0vs10,20,30		0.098	0.001*
0vs10		0.866	0.001*
0vs20		0.034*	0.016*
0vs30		0.040*	0.039*
10vs20,30		0.011*	0.151
10vs20		0.023*	0.380
10vs30		0.028*	0.107
20vs30		0.940	0.453

[a](*) Probable F is significant.

TABLE 6. Effect of soil applied N and foliar N on leaf N concentrations of cowpeas at Jackson, Tennessee, 1990 and 1991.

Treatment	Leaf N Concentration 1990	1991
Soil N (lb/A):	-----(% N)-----	
0	3.02	4.40
30	2.95	4.13
60	3.09	3.97
90	--	4.35
LSD	0.10	NS
Foliar N (lb/A):		
0	2.89	--
10	2.91	--
20	3.02	--
30	3.27	--
LSD	0.17	--

TABLE 7. Effect of P and K fertilizer rates on yield of green shelled cowpeas at Jackson, Tennessee, 1990 and 1991.

Level of P_2O_5	Level of K_2O	Mean Yield 1990	1991	2 Year Avg.
(lb/A)				
0	0	1559	771	1175
0	30	1585	807	1183
30	0	1579	828	1166
30	30	1572	751	1243
30	60	1556	690	1123
30	90	1414	731	1073
30	120	1565	749	1157
60	30	1662	784	1223
90	30	1549	744	1147
120	30	1440	609	1025
LSD		NS	NS	143

available P probably should be limited to 60 lb/A for cowpea production. Paterson and Blackhurst (43) obtained significant cowpea yield increases from P applications when soil P was very low. Stewart (59) reported no response from P on cowpeas grown on soil testing high in P.

Stewart (59) working with cowpeas, and Peck et al. (45) working with snap beans, reported a decrease in yield as applied K exceeded the amount of applied P. In 1990 and 1991, the data show a slight, although not significant decrease in yield as applied K_2O was increased from 30 to 120 lb/A. In 1990 and 1991, there was no significant effect on yields from soil applied K_2O fertilizer rates (TABLE 7).

Phosphorus and K application rates had no significant effect of leaf concentrations of P, K, Ca, or Mg (Table 8). Osiname (41) also observed this effect on leaf concentrations and raised the question of whether the cowpea relies more on the subsoil than on the surface for its nutrients.

Applying either 90 or 120 lb/A of P_2O_5 increased soil test P ratings from medium to high. Restricting K fertilization reduced the soil test K rating from medium to low (TABLE 9).

TABLE 8. Effect of P_2O_5 and K_2O rates on leaf concentrations of P, K, Ca and Mg in cowpeas at Jackson, Tennessee, 1991.

Fertilizer Rate (lb/A)	Leaf Concentrations P	K	Ca	Mg
	-----------(% Nutrient)-----------			
P_2O_5				
0	0.30	1.09	2.49	0.36
30	0.29	1.22	2.49	0.36
60	0.30	1.16	2.58	0.36
90	0.31	1.10	2.45	0.36
120	0.29	1.24	2.25	0.35
LSD	NS	NS	NS	NS
K_2O				
0	0.28	1.07	2.41	0.40
30	0.29	1.22	2.49	0.36
60	0.28	1.13	2.54	0.36
90	0.28	1.24	2.50	0.35
120	0.28	1.32	2.39	0.30
LSD	NS	NS	NS	NS

TABLE 9. Effect of P_2O_5 and K_2O fertilizer rates on soil pH and extractable P and K after the 1991 season at Jackson, Tennessee.

Fertilizer Rate P_2O_5	K_2O	pH	Extractable Nutrients P	K
----(lb/A)----			-----(lb/A)----	
0	0	6.0	24 M[a]	100 M
0	30	6.0	26 M	114 M
30	30	6.0	24 M	98 M
60	30	5.9	30 M	118 M
90	30	6.0	34 H	104 M
120	30	5.8	37 H	112 M
30	0	6.0	24 M	92 L
30	60	5.9	28 M	108 M
30	90	5.9	26 M	124 M
30	120	5.9	31 M	146 M

[a]Ratings: The letter following the level of the respective nutrient indicates relative availability of nutrients to plants in accordance with The University of Tennessee Agricultural Extension Service soil testing laboratory. (L)= Low; (M) = Medium; (H) = High.

IV. RATOONING

Cowpea yields for both the main and ratoon crops were unaffected by fertilizer treatments applied at planting (TABLE 10). The main crop was planted on May 24 and harvested on August 5 for a total of 73 days from planting to harvest. The ratoon crop was harvested on September 27, 53 days after the harvest of the main crop. Thus, ratooning reduced the days required to reach harvest by 20 when compared to the main crop. The ratooning process added another 1030 lb/A of shelled peas to the total yield or an increase of 77 percent. Mahendra and Kaushik (33) working with sorghum reported that the ratoon crop took less time to reach maturity and increased total yields by 170 percent in one variety and by 40 percent in another. Sarma et al. (55) reported and average yield increase of 36 percent from ratooning sorghum.

Depending on fertilizer treatment, the yield from the ratoon crop ranged from 63 to 100 percent of the main crop yield. The largest differences were noted with the 60 and 90 lb/A N rates. Although not significant, the main crop yield averaged higher for the 60 lb/A N rate when compared to the 90 lb/A N rate. Based on the foliar data (TABLE 5) applying 90 lb/A of N slightly reduced yields when compared with the 60 lb/A N rate. Accordingly, main crop yield may have been higher if lower N rates had been applied. Yields from the ratoon crop increased with fertilizer rates of 90 lb/A of N applied at planting (TABLE 10). Although available soil N was not evaluated, these observations suggests a N carryover to the ratoon crop. This being true, N rates applied for the main crop need to be reduced, with additional N fertilizer applied to the ratoon crop. A second grain yield is not feasible when it depends upon a seconding planting of cowpeas in late July or early August. A second grain yield by ratooning of the first planting of cowpeas is very possible.

V. STARTER FERTILIZER NUTRIENT COMBINATIONS

Starter fertilizers did not have a positive effect on cowpea yields (TABLE 11). Randall (51) working with conventional-till corn reported similar results. Yields ranged from 1077 to 1200 lb/A, with no marked differences due to the broadcast or the band treatment. Again, this may or may not have been due to unfavorable climatic conditions in 1991. These data suggest that starter applications are not beneficial and may add extra expenses to the producer because of equipment and time required for application.

TABLE 10. Effect of fertilizer treatment and ratooning on yield of green shelled cowpeas at Jackson, Tennessee, 1991.

Fertilizer Treatments					Harvests		
Broadcast		Band		Foliar	Main	Ratoon	Total
N	P_2O_5	N	P_2O_5	N	Crop	Crop	Crop
(lb/A)							
45	15	15	15	0	1446	906	2351
45	15	15	15	30	1305	972	2278
75	15	15	15	0	1258	980	2238
90	30	0	0	0	1259	1261	2519
60	30	0	0	30	1314	1107	2422
60	30	0	0	0	1368	955	2323

Statistical analyses done with the GLMM program (4). Multiple means comparison at Alpha = 0.05 showed no significant differences among treatment mean yields.

TABLE 11. Effect of starter fertilizer treatments on yield of green shelled cowpeas at Jackson, Tennessee, 1991.

Fertilizer Treatments						
	Broadcast			Starter		
N	P_2O_5	K_2O	N	P_2O_5	K_2O	Yield
(lb/A)						
45	30	30	15	0	0	1186
45	15	30	15	15	0	1106
45	0	30	15	30	0	1163
30	30	30	30	0	0	1146
30	0	30	30	30	0	1200
60	30	30	0	0	0	1077

Statistical analyses done with the GLMM program (4). Multiple means comparisons at Alpha = 0.05 showed no significant differences among mean treatment mean yields.

CHAPTER V

SUMMARY AND CONCLUSIONS

The results indicates that N source need not be a major concern for cowpea production. Nitrogen rates above 30 lb/A did not increase yields. Even when rates were split with one half at planting and one half at flowering, yields were not increased. Yields were slighlty depressed with N rates of 60 and 90 lb/A, suggesting that N rates should not exceed 30 lb/A.

Yield responses from foliar applied N indicated that foliar fertilization has potential for increasing cowpea yields. Foliar applications of 20 lb/A N at flowering time increased cowpea yields significantly in 1990 when soil N may have been immobilized by plant residue. In 1991 when there was no immobilization of soil N, 10 lb/A of foliar applied N showed a significant increase in yield. If available soil N is sufficient, foliar N rates may be reduced to 10 lb/A. The data indicates that broadcast applications of 30 lb/A N plus foliar applying 10 lb/A N is sufficient for cowpea culture under most growing conditions.

The results of the P and K study indicate a more probable yield response of cowpeas to applied P than to K. Phosphorus and K rates of up to 120 lbs/A had no significant effect on cowpea yields for either 1990 or 1991. Applying 90 and 120 lb/A P_2O_5 reduced two year average yields when compared with the 60 lb/A rate. Applying either 90 or 120 lb/A of P_2O_5 increased soil test P from medium to high. Soil applied K fertilizer rates show no effects on cowpea yield, however, available soil K should be maintained at medium to avoid a possible yield decrease resulting from K deficiency. Restricting K fertilization reduced the soil test K rating from medium to low.

Ratooning of cowpeas appears to be an excellent production practice for increasing yields. Ratooned crop yields were approximately 78 percent of the main crop, and harvest time was reduced by 20 days. Applying N rates lower than 60 lb/A to the main crop followed by 30 lb/A to the ratoon crop should result in higher overall yield totals. A second grain yield is not feasible when it depends upon a seconding planting of cowpeas in late July or early August. However, a second grain yield by ratooning of the first planting of cowpeas is very possible.

Starter nutrient combinations applied at planting had no effect on cowpea yield. Additional research is needed to identify soils and growing conditions for which good responses are most likely.

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APPENDIXES

APPENDIX A

I. Procedure for the digestion of plant tissue for determination of K, Ca, Mg, and P.

1. Dry plant tissue at 68^{0}C, grind into fine particles (40 mesh screen), and store in air tight container.

2. Weigh a 0.2 gram sample and place in a labeled Erlenmeyer flask.

3. Add 10 ml of concentrated H_2SO_4 to each Erlenmeyer flask and allow to pre-digest for four hours or more at room temperature.

4. After pre-digesting, set the flasks on a hot plate and heat to 200-234^{0}C for 1.5 to 2 hours, or until the volume is reduced by about 50%.

5. Remove flasks from the hot plate and allow to cool.

6. After sufficient cooling, add 10 ml of 35% H_2O_2 to each flask and reheat at 200-234^{0}C for 45 minutes or until clear.

7. Remove clear samples from the hot plate, cool, and transfer to 250 ml volumetric flasks.

8. Wash sides of flasks with demineralized water and reheat for 15 minutes at 200-234 ^{0}C.

9. Fill to volume with distilled water, shake thoroughly, and allow samples to equilibrate.

APPENDIX B

Daily rainfall in inches during the growing season, 1990, collected at the NOAA weather station located at the West Tennessee Experiment Station, Jackson, TN.

	Month					
DAY	APR	MAY	JUN	JUL	AUG	SEP
1	0	T	0	0	0	0
2	0.10	0.58	0.01	0	0	0
3	0	0.29	0.83	0	0	0
4	0	T	0	0	0	0
5	0	0.10	0	0	0.33	0
6	0.38	0	0	0	0.19	0
7	0.04	0	0	0	0	0
8	0	0	0	0	0	0.01
9	0	0	0	0	0	0.14
10	0.02	0.06	1.55	0	0	0
11	0.24	0	0	0.05	0	0.01
12	0	0.12	0	3.44	0	0.14
13	0	0.29	0	0.61	0.13	0.03
14	0.01	0	T	0	0.29	T
15	0.15	0	0.72	0	0	0.23
16	T	0	0.25	0	0	0
17	1.56	1.05	0	0	0	0
18	0.27	0	0	0	0	0
19	0	0	0	0	0	0.02
20	0	1.18	0	0	0	T
21	1.33	0.77	0.22	0	0	T
22	0.01	0	1.57	0.20	0	0.15
23	0	0	0	0.12	0	0
24	T	0	0	0.02	0	0
25	T	T	0	0	0	0
26	0	0	0	0	0	0
27	0	0	0	0	0	0
28	1.79	0.04	0	0	0	0
29	0.13	0.04	0	0	0	0
30		0	0	0	0	0
31		T		0	0	
TOTAL	6.03	4.52	5.15	4.44	0.94	0.73
NORMAL	5.39	4.94	3.84	4.06	2.88	3.69

RAINFALL FOR SEASON 21.81

NORMAL SEASON RAINFALL 24.87

APPENDIX C

Daily rainfall in inches for the growing season, 1991, collected at the NOAA weather station located at the West Tennessee Experiment Station, Jackson, TN.

	----------------Month----------------					
DAY	APR	MAY	JUN	JUL	AUG	SEP
01	0	0	0	T	0	0
02	0	0	0.26	0.2	0	0.38
03	0	0	0	0.3	0	0.01
04	0.30	0.22	T	0	0.06	0
05	0.19	1.67	0.16	0	0	0.04
06	0	0.02	0	0	0	0.92
07	0	0	0	0	T	0
08	0.41	0	0	0.08	0.57	0
09	0.02	0.55	0	0	0.18	1.24
10	0.47	0.07	0	0	0	0.03
11	0	1.03	0.23	0	0	0
12	0.50	0.88	0.68	0	0	0
13	0.50	1.00	0.11	0.05	0	0
14	1.53	0.25	0	0	0	0
15	0.81	0	0	0	0	0
16	0	0.76	0.09	0	0	0
17	0	0	0	0	0	0
18	0	1.72	0	0	0	0
19	0.15	T	0	0	0	0.14
20	0.01	0.10	T	0	0	0
21	0	0	0.41	0	0	0
22	0.02	0	1.60	0	0	0
23	T	T	0.05	0.07	0	0.03
24	0	0.07	T	1.80	0	0.68
25	0	0.10	2.58	T	0.06	0.06
26	T	0.89	T	0	T	0
27	0.18	0.99	0	0	0.03	0
28	1.65	0	0	0	0.02	0
29	0.96	T	0	0	0.42	0
30	0	0	0	0	0	0
31		0	0	0		
TOTAL	7.70	10.32	6.17	2.50	1.34	3.53
NORMAL	5.39	4.94	3.84	4.06	2.88	3.69

RAINFALL FOR SEASON 31.56

NORMAL SEASON RAINFALL 24.87

APPENDIX D

OVERALL ANOVA FOR N SOURCES STUDY IN 1990: variables are Rep (Rep), Rate (R), Source (S), and Time (T).

General Linear Models Procedure

<u>1990 N Source ANOVA</u>

Dependent Variable = YIELD

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	4	1052518.5	263129.6	10.15	1.E-05
R	1	275.7	275.7	0.01	.91841
REP*R	8	449721.4	56215.2	2.17	.05316
S	3	138976.5	46325.5	1.79	.16644
R*S	3	151961.0	50653.7	1.95	.13775
REP*R*S	24	876235.6	36509.8	1.41	.17040
T	1	27073.8	27073.8	1.04	.31336
R*T	1	6939.7	6939.7	0.27	.60790
S*T	3	30649.8	10216.6	0.39	.75787
R*S*T	3	146926.5	48975.5	1.89	.14823

Tests of Hypotheses using the Type III MS for REP*RATE as an error term.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
RATE	1	275.65312	275.65312	0.00	.94589

Tests of Hypotheses using the Type III MS for REP*RATE*SOURCE as an error term.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SOURCE	3	138976.52	46325.51	1.27	.30744

APPENDIX E

OVERALL ANOVA FOR N SOURCES STUDY IN 1991: variables are Rep (Rep), Rate (R), Source (S), and Time (T).

General Linear Models Procedure

1991 N Source ANOVA

Dependent Variable = YIELD

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	4	32328.12	8082.03	0.75	.56990
R	2	69355.69	34677.85	3.24	.06608
REP*R	8	185193.33	23149.17	2.16	.09040
S	4	6172.24	1543.06	0.14	.96307
R*S	6	52565.53	8760.92	0.82	.57224
REP*R*S	40	446450.44	11161.26	1.04	.48588
T	1	4433.13	4433.13	0.41	.52926
R*T	0	0.00	.	.	.
S*T	3	39499.80	13166.60	1.23	.33187
R*S*T	0	0.00	.	.	.

Tests of Hypotheses using the Type III MS for REP*RATE as an error term.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
RATE	2	69355.692	34677.846	1.50	.28017

Tests of Hypotheses using the Type III MS for REP*RATE*SOURCE as an error term.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SOURCE	4	6172.2376	1543.0594	0.14	.96711

APPENDIX F

<u>ANOVA for N Sources 1990:</u> variables are Rate and Source with Time of application held constant at planting.

Dependent Variable = YIELD.

1990:

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	4	708422.85	177105.71	3.84	.01049
RATE	1	2224.57	2224.57	0.05	.82747
SOURCE	3	138799.91	46266.64	1.00	.40279
RATE*SOURCE	3	194184.09	64728.03	1.40	.25762

<u>ANOVA for N Source 1991:</u> variables are Rate and Source with Time of application held constant at planting.

Dependent Variable = YIELD.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	4	24860.86	6215.22	0.39	.81180
RATE	2	69355.69	34677.846	2.20	.12301
SOURCE	3	14826.13	4942.04	0.31	.81564
RATE*SOURCE	6	52565.53	8760.92	0.56	.76301

APPENDIX G

<u>ANOVA for N Source 1990:</u> variables are Source and Time of application with all treatments being split, and applied at preplant and flowering.

Dependent Variable: YIELD

General Linear Models Procedure

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	4	780114.07	195028.52	5.84	.00053
SOURCE	3	138976.52	46325.51	1.39	.25587
REP*SOURCE	12	571369.86	47614.15	1.43	.18147
TIME	1	27073.76	27073.76	0.81	.37160
SOURCE*TIME	3	30649.81	10216.60	0.31	.82083

Tests of Hypotheses using the Type III MS for REP*SOURCE as an error term.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SOURCE	3	138976.52	46325.51	0.97	.43754

<u>ANOVA for N Sources 1991:</u> variables are Source and Time of application, with only the 60 lb/A N rate being split.

General Linear Models Procedure

Dependent Variable = YIELD

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	4	84963.20	21240.80	1.57	.19436
SOURCE	4	6518.73	1629.68	0.12	.97457
REP*SOURCE	16	176441.38	11027.59	0.82	.66206
TIME	1	6687.65	6687.65	0.50	.48461
SOURCE*TIME	3	34632.16	11544.05	0.85	.47013

Tests of Hypotheses using the Type III MS for REP*SOURCE as an error term.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SOURCE	4	6518.7256	1629.6814	0.15	.96132

APPENDIX H

ANOVA for 1990 Foliar Test: variables are soil applied N (N), and foliar applied N (F).

General Linear Models Procedure

Dependent Variable: YIELD

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	4	622058.6	155514.6	9.15	3.E-05
N	2	1068108.4	534054.2	31.43	1.E-08
REP*N	8	386124.0	48265.5	2.84	.0149
F	3	172584.3	57528.1	3.39	.0284
N*F	6	93608.0	15601.3	0.92	.4933

Tests of Hypotheses using the Type III MS for REP*N as an error term.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
N	2	1068108.4	534054.2	11.06	.00497

ANOVA for 1991 Foliar Test: variables are soil applied N (N), and foliar applied N (F).

General Linear Models Procedure

Dependent Variable: YIELD

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	4	63035.07	15758.77	2.67	.04312
N	3	86753.09	28917.70	4.90	.00472
REP*N	12	96127.42	8010.62	1.36	.21896
F	3	91566.27	30522.09	5.18	.00352
N*F	9	80795.35	8977.26	1.52	.16738

Tests of Hypotheses using the Type III MS for REP*N as an error term.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
N	3	86753.09	28917.697	3.61	.04577

APPENDIX I

ANOVA for 1990 P and K fertilization test: variables are P and K.

General Linear Models Procedure

Dependent Variable: YIELD

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	4	294934.88	73733.72	1.67	.17751
P	4	190881.30	47720.32	1.08	.37941
K	4	189227.01	47306.75	1.07	.38385
P*K	1	79002.45	79002.45	1.79	.18896

ANOVA for 1991 P and K fertilization test: variables are P and K.

General Linear Models Procedure

Dependent Variable: YIELD

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	4	74696.34	18674.09	1.08	.38207
P	4	121658.25	30414.56	1.75	.15949
K	4	27940.91	6985.23	0.40	.80519
P*K	1	15691.20	15691.20	0.91	.34771

VITA

McKinley Posely III was born in Chattanooga, Tennessee, on September 17, 1951, where he attended and graduated from Howard High school. In May of 1979, he received a Bachelor of Science degree in Agronomy from the University of Minnesota at St. Paul, MN.

In November of 1983, after taking a leave of absence from the U. S. D. A. Soil Conservation Service in Minnesota, he began a two year assignment as a Peace Corps Volunteer in Niger, West Africa. He worked primarily as an Agriculture Extension and Rural Development Agent demonstrating Ag production techniques and installing wells for drinking water.

In August of 1990, after returning from an extended overseas tour of six years, he accepted a graduate research assistantship with the Plant and Soil Science Department at the University of Tennessee. In December of 1992, he received a Master of Science degree in Plant and Soil Science with emphasis in vegetable production.