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I am submitting herewith a thesis written by Shannon Loriece Morris entitled "Preliminary Results of the Effects of Annual Fertilizer Rates on Tomato, Cabbage, Lima and Snap Bean Yield and Quality." 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.

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PRELIMINARY RESULTS OF THE EFFECTS OF ANNUAL FERTILIZER
RATES ON TOMATO, CABBAGE, LIMA AND SNAP
BEAN YIELD AND QUALITY

A Thesis
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DEDICATION

This Master's Thesis is dedicated to Mrs. Daisy Bell Nolen Sherrill, the author's maternal grandmother, to whom it represents a dream completed. Without her financial assistance and motivating influence the goal would never have been realized.

Tiffany and Jonathan Morris share also in the dedication as their motivating influence, though unwitting, was no less real.

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ABSTRACT

Due to the comparatively low costs of fertilizer elements in recent years, vegetable growers have, in the past, frequently applied more fertilizer than soil tests have called for and have therefore raised the phosphorus and potassium levels to a point where additional applications may not significantly increase yields. In an attempt to determine what benefits can be obtained from further fertilization of these high testing soils, and to what degree fertilizer rates could be cut without significantly reducing yields, a five year study was undertaken at the University of Tennessee Plant and Soil Science Farm, the Plateau Experiment Station at Crossville, and the West Tennessee Experiment Station at Jackson. Tomatoes on one set of plots and cabbage followed by lima or snap beans on another were grown under seven different fertilizer regimes. Fertilization rates ranged from no fertilizer to 134 kg./ha. of nitrogen, phosphorus and potassium. The experiment was to be run on the same plots for five consecutive years. The first year's results at all locations, and the second year's at the Knoxville location only, were available and included in this report.

Generally it was found that cabbage and tomatoes responded to nitrogen, a fertilizer element known to not carry over well at this southern latitude. Phosphorus and potassium response was not as pronounced in cabbage and was, in many cases, not evident. Lima and snap beans were, for

the most part, adequately supplied by residual phosphorus and potassium levels in the soil. When they did show a response, it was between no fertilizer and the application of the first increment, with no apparent correlation between amount of fertilizer applied and yield of beans.

These preliminary results suggest that any decrease in fertilizer rates to counter increased fertilizer prices, which does not result in a decrease in yield, quality, or a delay in maturity will net the grower a wider margin of profit.

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I. LITERATURE REVIEW

Nitrogen Nutrition of Tomatoes

Nitrogen deficiency symptoms periodically occur during August and September in many tomato producing areas (18). Under certain conditions this deficiency, usually expressed as a general yellowing of the foliage and a reduction in plant growth, may occur on almost all soil types. Howlett (8) reports N deficiency will not retard microsporogenesis or the development of the male gametophyte, yet Reeve et al. (18) found, in general, applications of supplemental N increased the number of fruit set per plant. In addition, foliage remains green longer resulting in improved fruit quality due to less sunscald, although yields have not always been increased by supplemental N applications due, in most instances, to delayed ripening. Size of fruits is also affected by N fertility in that treatments which produce the highest yields also produce the smallest fruits.

Nicklow and Downes (13) report no effect of N on yield and maturity of tomatoes in some instances and a reduction of early yield and delayed anthesis with increasing N applications in others. Both preplant and sidedressed N result in a reduction of early once-over harvest yields of canners and a decrease in fruit size. Barker et al. (3) found tomato plants developed severe, necrotic stem lesions when grown in soils fertilized heavily with ammonium N. These lesions appeared on the

leaf petioles and laminae after prolonged periods of continuous ammonium nutrition and were found to be closely related to a reduction in the K^+ supplying power of the soil. The study by Barker et al. (3) indicated that NH_4^+ ions cause a trapping of K^+ in the soil, and hence, induce a K^+ deficiency. Jaworski and Morton (9) report high fertilization may cause seedlings to become too succulent, with resultant susceptibility to disease and physical damage during handling and transplanting.

Tomato production is usually best when only enough N is available during the first two or three months after transplanting to permit the development of a large sturdy vine, but not enough to give a soft type of growth. Once the plant has a heavy fruit load and tomatoes begin to ripen, the N requirement is very high. If the N supply is not adequate at this stage of development the plants will turn yellow and defoliate leaving the fruits exposed and vulnerable to sunscald.

Many factors influence the availability of soil N. Some of the more important ones are (1) type and amount of soil organic matter, (2) soil texture and structure, (3) moisture, (4) temperature, (5) soil reaction, and (6) soil microorganisms. Since there are so many factors, some of which are uncontrollable, it is difficult to recommend supplemental N with the same precision as is possible with phosphorus and potassium. The amount of N available to the plant, either from the soil or supplemental application, is

therefore an individual field and seasonal problem and must be evaluated and adjusted as the season progresses.

Phosphorus Nutrition of Tomatoes

The main effects of a phosphorus deficiency are reduced yields and delayed maturity (6). The reduction in yield is due to a reduction in the number of fruits per plant rather than a reduction in fruit weight. Arnold and Schmidt (1) observed that the lowered number of fruits on P deficient plants was associated with smaller plants with fewer flower clusters rather than the dropping of blossoms. Hepler and Kraybill (6) made similar observations and found also a slight increase in the number of blossoms per flower cluster where the deficient plants were treated with acid phosphate. The addition of acid phosphate was also found to hasten the maturity of the tomato due to a more rapid growth of the plants in the early part of the season, and, consequently, more blossom clusters, more blossoms, and more fruit are produced. In general though, only when P is deficient will an application accelerate early growth and promote early maturity.

Potassium Nutrition of Tomatoes

Barber and Humbert (2) report potassium is required in carbohydrate metabolism and translocation, in N metabolism and protein synthesis, for regulation of cell sap concentration, as an enzyme activator, to promote meristematic growth and cell expansion and for stomatal

movement in water regulation. Deficient young plants have darker green leaves with smaller stems and shorter internodes than plants which receive adequate K (23). The vine tips of deficient plants often have a spike-like appearance due to the slower development of the laterals. Intervenial necrosis of the leaves occurs in the later stages of deficiency.

On K deficient plants, Wilcox (27) found much fruit dropped from the vine when it ripened. If the fruit did not drop from the force of gravity, Wilcox reports, it would drop at the slightest jar. In his tests the fruit on plots receiving K treatments were firmly attached to the vine with a sturdy pedicel whereas on deficient plants, the sepals and the stem between the fruit and the abscission layer of the pedicel were dead. The pedicels of mature fruit from no K and 400 pounds per acre treatments of K showed a difference in structural development across the abscission zone. There were many more tiers of small cells in the separation zone of the K deficient pedicel than in the separation zone of the pedicel from a non-deficient plant. When the fruit ripened on the K deficient plant, abscission occurred across the abscission layer.

Tiedjens and Wall (23) report earlier fruit setting in K deficient plants but comparatively few fruits reaching maturity due to the formation of the abscission layer in the pedicel and subsequent fruit drop. Those that did develop were small and several developed blossom-end rot.

However, Wilcox found early fruits of K deficient plants to be as large as those from K treated plants and the quality grade of fruit picked up soon after they dropped not to be affected by treatment. Wilcox noticed a deterioration of fruit quality on the deficient plots as the season progressed. This reduction in grade of fruit was cited as responsible for the U. S. Number 1 and 2 grade tomato yield responses to K treatments. These responses were greater than were total yield responses because of the K influence on quality late in the season.

In general, increasing the N, P and K levels of fertility of tomatoes will result in a larger, more vigorous plant which has more flowers per cluster, more clusters per plant, and will set more fruit than a plant deficient in one or more of these elements. Other parameters affected by fertility level are earliness, fruit size, fruit drop, and fruit quality. Vittum and Tapley (24) suggest that at the higher fertility levels the plants may be able to set so many fruit per plant that the gross drain of minerals and carbohydrates will be larger and result in small fruit. The larger yield of plants grown under conditions of high fertility would then be a function of the larger number of fruit harvested per plant.

Nitrogen Nutrition of Cabbage

Thomas et al. (19) reported N fertilization of cabbage to have increased yields, plant uniformity and

quality. The increase in the number of marketable heads with an increase in the rates of N fertilization was credited with a larger contribution to the total yield than the increase in average head size. They found rates of application above 80 pounds of N per acre did not further increase the average head weight. Although increasing N rates increased yields, they did so at a diminishing rate. Oyer (13) agreed to the importance of N in cabbage production and cited N as the element most likely to limit cabbage production as a result of the high N requirements of cabbage.

Oyer (13) also noted that the ammonium form of N is retained on clay particles in the soil, rendering it available to the plants over a long period of time. The ammonium form is also available to bacteria that convert it to the nitrate form. The nitrate form, however, is not retained on the clay particles and is readily leached from the soil by excessive rains or irrigations. Boswell (4) observed that nitrates are produced very slowly, if at all, when the soil is cold and waterlogged. Because most forms of N are ultimately converted to the leachable nitrate form, and the cabbage plant is able to grow so early in the spring and at such cool temperatures, it is often necessary to apply N to the crop during the growing season.

Ware and Johnson (25) noted the need for high levels of fertilizer N for high yields on both old and new land. Levels as high as 150 pounds of N per acre on old land and

180 pounds of N per acre on new land were needed for maximum or near maximum yields. They attributed this similarity to the low carry-over of residual N, especially on light soils.

Phosphorus and Potassium Nutrition of Cabbage

Ware (26) reported that on soils to which no fertilizer or small amounts had been applied in recent years, P appeared to be the most limiting factor and N second. The response to K was small. Crop yields were much higher on old land from no-P treatments than on new land, although about the same amount of P was required on old as on new land for maximum or near-maximum yields. The same type of response was obtained with K, old land that had received some K showed less response than new land that had received no K.

Ware stated that large quantities of P are fixed in the soil and that plants may utilize much of this fixed P at later periods. In one experiment P and K applications both affected the yield of crops for many years and at another location, land that had been heavily fertilized in recent years produced high yields without the application of P, K, or N.

Peck (17) observed the effects of P and K on fresh weight and dry weight were greatest at the seedling stage of growth and gradually became less as the plants become more mature. Potassium in the form of muriate of potash increased the percentage of K in the plants at the stages of growth

and development whereas P applications generally decreased the percentage of K in plant tissues grown at low levels of K. The effect of P on the percentage of K in plant tissues was lessened on plants grown at higher levels of K.

Peck found that during the growing season, the plants grown with high rates of P and at low rates, or without K had scorched leaf margins. Moreover, black tissue occurred as sunken areas on the dorsal side of the petioles, beginning about 1/4 inch from the injury. A cross section of a petiole showed that the cytoplasm in the parenchyma cells had collapsed, blackened, and hardened on the walls of the cells. This black tissue was evident only at the late harvests.

Peck observed the plants grown with the high rates of K produced the greatest number of burst heads, and the lowest number of heads with black tissue in the petioles. None of the burst heads was observed to contain black tissue in the petioles. Chemical analysis of petioles showed that if the petioles contained over about 1 percent K on a dry weight basis, the tissue was not discolored.

Cabbage fertilized with very high levels of P and K produced heads displaying excellent vegetative growth, yet produced an extremely loose internal pack which accentuated shatter and caused excessive loss during the kraut shredding operation. Peck concluded applications of 300 pounds of concentrated superphosphate and 240 pounds of KCl were adequate for good yields of whole heads.

Nitrogen Nutrition of Lima and Snap Beans

Lambeth (11) reports that excessive N fertilization of lima beans serves to stimulate vegetative growth at the expense of fruitfulness. In addition, with respect to a species comparison, the fertilizer requirement of the lima bean is similar to that of the snap bean, but, observes Lambeth, it is probable that the lima bean plant can use more N to advantage. The results obtained with fertilizer application to increase yield of lima bean seed are inconsistent, depending upon various factors which may become limiting. Tiedjens and Schermerhorn (22) working on the fertilizer requirements for lima beans in New Jersey found that the 'Fordhood' variety has a relatively high requirement of N, higher than the small seeded variety, 'Jackson Wonder'. They obtained a large increase in yield of 'Fordhood' by increasing the N from 32 to 90 and 160 pounds per acre but no increase in the yield of 'Jackson Wonder' from increasing the N above 32 pounds per acre.

Patterson et al. (16) report that for limas, the size, grade, and percent seed quality are attributes which can be affected by N applications. From the results of their experiments at several locations in the United States, they reported varying responses to N fertilization ranging from no response to great increases in percent seed and total yield. As the yields increased, the percent seed increased. The K concentration in the leaves was reduced about .075

percent of the dry weight with each 25 pound per acre increment of N applied. Concentration of P was curvilinearly associated with rate of applied N, with the estimated maximum of P being obtained with a calculated 42.8 pounds per acre of N.

Ware (25) reported yields of snap beans that were greatly increased by applications of N. In one experiment, yields were progressively increased from 68 to 270 hampers per acre, as the rate of application was increased by 30 pound increments from 0 to 120 pounds of N to the acre. He noted a reduction in the yield of early beans but an increase in the yield of the total crop due to increased applications of N. Patterson et al. (16) concur that N fertilization results in a significant increase in pod yield.

II. MATERIAL AND METHODS

Field Procedures

Sites were selected at three locations across Tennessee, the University of Tennessee Plant and Soil Science Farm at Knoxville, the Plateau Experiment Station at Crossville, and the West Tennessee Experiment Station at Jackson, all of which had been in vegetable production in recent years. The plots were identified and maintained for the duration of the five year study. The plots were made up of three rows of each crop, 5.68 meters long and 1.10 meters wide. The center rows only, of each crop were harvested for records. The experimental design was of the randomized complete block design with the plots split and tomatoes and cabbage grown side by side. The cabbage was followed by lima beans at Knoxville and Jackson and snap beans were used at Crossville. The treatments consisted of seven different application rates of fertilizer with the experiment being replicated four times.

Greenhouse grown tomato plants of the 'Big Seven' cultivar were transplanted in the spring after the danger of frost had passed and pulled cabbage plants, of the 'Head Start' cultivar, were transplanted about two to three weeks earlier. 'Jackson Wonder' cultivar lima beans were direct seeded after the cabbage was harvested, in the first week of July.

At the Knoxville location the plots were kept weed free through the use of herbicides supplemented with mechanical

methods. DCPA was used the first year on both the tomatoes and the cabbage/bean plots. The second year no herbicide was applied to the cabbage/bean plots and Diphenamid was applied to the tomatoes. PCNB was applied preplant to the lima beans at the rate of three pounds per acre to control root and stem rot. Supplemental irrigation was applied as needed.

The tomatoes were trained to the two-stem method. Supplemental nitrogen was applied to all treatments except the non-fertilized control as a side-dress. Ammonium nitrate was used as the nitrogen source at the rate of 34 kg./ha. when the fruits had reached 3 to 6 cm. in diameter. The cabbage/bean plots were sidedressed at the same rate when the heads of the cabbages were 7 to 10 cm. in diameter. No additional fertilizer was applied to the bean plots. The pH of the plots was adjusted to, and maintained in, the range of 6.0 to 6.5 throughout the study.

The cabbages and beans were once-over harvested while the tomatoes were repeatedly harvested twice per week at the breaker stage. Yield data for the cabbage consisted of (1) total weight of heads, (2) number and weight of marketable heads, and (3) average weight of marketable heads. Lima and snap bean yield data were limited to (1) total weight of beans in pods, (2) percent shell out, and (3) total yield of shelled beans for limas only. Tomato yields were broken into classes (1) early yield, (2) total yield of U. S. Grade Number 1's and 2's, (3) average weight of number 1's and (4) total yield.

Laboratory Procedures

Tissue samples were taken from the petioles of the fourth wrapper leaf from the cabbage head when the heads were from 7 to 10 cm. in diameter and before the plots were sidedressed. The third fully developed leaf from the growing tip was taken from the tomatoes when the fruits were 3 to 6 cm. in diameter and before the plots were sidedressed. The petioles of the second or third leaf from the growing tip were sampled from the bean plants. Samples were oven dried at 70°C and stored in air-tight plastic bags until they could be analyzed.

Parts per million of $\text{NO}_3^- \text{N}$ were obtained by shaking .50 gm. of the dried tissue in 50 ml. of deionized water for 5 minutes. The filtrate was then measured with a nitrate probe on an Orion parts per million counter.

The P and K contents were determined by a wet oxydation method. A .40 gm. sample was placed in a 75 ml. test tube and 10 ml. of nitric acid was added. A small condensation funnel was placed in the mouth of the test tube and the contents heated at a slow boil until only 25 percent of the original volume remained. The test tube was then removed from the heat and 10 ml. of perchloric acid was added, the condensation funnel replaced and the mixture returned to a low boiling temperature until all organic matter was oxidized from the sample. The solution was then allowed to cool and 5 ml. of hydrochloric acid and 10 ml. of deionized water was added. The solution was again heated until all

salts were dissolved. After filtering into a 250 ml. volumetric flask the solution was brought to volume with deionized water and a sample then analyzed for P and K on a Technicon Auto-analyzer.

Soil samples were taken at the start of the study and after the harvest of each year's crops. These samples were sent to the State Soil Testing Laboratory in Nashville and tested for P, K, and pH.

The data were subjected to an analysis of variance by the University of Tennessee computer and Statistical Analysis System (S A S) (18). The means were compared by the Least Significant Difference method.

III. RESULTS AND DISCUSSION

Tomato Yields

Early tomato yields were considered as that part of the crop of U. S. number 1 and 2 quality, which was harvested in the first two weeks of picking (Tables 1, 2, 3, and 4, Appendix). A significant (Significance was calculated at the 1 percent level of probability in all instances) response to N fertilization was achieved only at the Knoxville location in the 1975 season (Table 1, Appendix). The response was further limited to the first increment of N applied.

Total marketable yield applies to the total seasonal yield of both U. S. number 1 and 2 grade tomatoes. Total yield applies to the total marketable and culls combined. In the case of both total yield and total marketable yield, only the 1975 season at the Knoxville location produced any significant increases in yields from N fertilization (Table 1, Appendix) and that increase was due to only the first increment applied.

Fruit size, the final tomato parameter measured, is the average weight in grams of the U. S. number 1 and 2 fruit. Fertilization with N produced a significant response in fruit size only in the same instance as the other tomato data, that is, the first increment of N at the Knoxville location in 1975. At no other location, or at Knoxville in 1976 did the addition of P or K above the initial combined

P and K increment increase fruit size significantly (Tables 1, 2, 3 and 4, Appendix).

Cabbage Yields

In the first year of the experiment increases in the rate of nitrogen fertilization resulted in significant increases in total yield of cabbage at the Knoxville location (Table 5, Appendix). The initial application of 67 kg./ha. of nitrogen (N) increased production above the control by 30.0 metric tons / ha., nearly twice the increase obtained by increasing N fertility from 67-134-134 kg./ha. to 134-134-134 kg./ha. Increasing N fertility at the Jackson and Crossville locations, however, did not increase yields (Tables 6, 7, Appendix). The initial application of 67 kg./ha. of N the second year at Knoxville increased yield as did the additional N between the 67-134-134 kg./ha. treatment and the 134-134-134 kg./ha. treatment (Table 8, Appendix).

Cabbage response to phosphorus fertilization was minimal. At no location did an increase from 67 to 134 kg./ha. produce a significant increase in yield (Tables 5, 6, 7, and 8, Appendix). Perhaps if the experiment had been designed to measure the response of the initial application of P then a significant increase in yield may have been found. As it was the first increment of P was applied with the first increment of K and 67 kg./ha. of N. Under such conditions the increases attributable to P could not be separated from those attributable to N and K.

The effects of the first increment of potassium were inseparable for the same reasons stated above for that of P. Response to the second increment, from 67 to 134 kg./ha., however, was greater than the responses to the same levels of P at the Knoxville location the second year. Again, had the treatments been composed so as to compare an initial K application treatment with a control receiving no K differences might have been greater. The greatest response to both P and K is, as reported in the literature, most frequently associated with the first increment applied.

Where the levels of fertility were raised from 67-0-0 kg./ha. to 67-67-67 kg./ha. significant differences were obtained at two locations (Tables 6 and 7, Appendix). The Crossville yields were different between 67-0-0 kg./ha. and 67-67-67 kg./ha. but not between the 67-67-67 kg./ha. and 67-134-134 kg./ha. treatments. This was due to a slight although not significant, decline in yield following the addition of P and K beyond the intermediate level. A decline of this sort might be attributable to the lower initial fertility level of the Crossville plots. In such an instance an increase in soluble K salt concentrations would give rise to even higher concentrations in the soil solution should water become limiting during the growing season. These higher soluble salt concentrations would then inhibit growth of the root system and possibly cause a nutrient imbalance in the plant due to preferential uptake of monovalent ions such as K^+ . The yield data for the Crossville location (Table 7, Appendix) appear to support

this hypothesis. The addition of K, and P and K above the initial 67 kg./ha. increment caused a decline, although not significant, in yields. The reduction in yield was confined to cabbage yields only and was not evident in the snap beans which followed on the same plots. At Jackson the differences in yield were simply not large enough to be significant until P and K fertilizations were increased 134 kg./ha. above the 67-0-0 kg./ha. control.

Application of N increased the average head weight at both levels compared at the Knoxville location in 1975 (Table 5, Appendix). Neither increment produced a significant increase in head weight at the Jackson or Crossville locations (Tables 6 and 7, Appendix). Yield differences, as related to N applications, also failed to vary significantly in 1976 at the Knoxville location (Table 8, Appendix).

At all locations differences between yields due to P fertilization fell short of significant levels (Tables 5, 6, and 7, Appendix). The decrease noted previously in the total yield at Crossville was evident again in both P and K treatment effects on average head weight (Table 6, Appendix). However, as before, the decrease was very slight and not statistically significant. The 1976 yield data at Knoxville indicate head weight increased significantly as a result of K fertilization (Table 8, Appendix).

Where P and K were increased together, increases in head weight were only obtained in two instances, one at

Crossville and the other at Jackson. Crossville increases were only significant when the first 67 kg./ha. of P and K were applied (Table 6, Appendix). Additional P and K caused, again, a slight but not significant decline in average head weight. Yield increases at Jackson were only significant where levels of P and K were raised from 0 to 134 kg./ha., the intermediate levels being insufficient to increase head weights (Table 6, Appendix).

Only at the Knoxville location are the results of the 1976 crop yield available at this writing. Examination of data in Tables 5 and 8, (Appendix), will reveal that yields and average head weight decline on all but three treatments from 1975 to 1976. Surprisingly, the three which showed an increase were not the highest levels of fertilizer application, in fact, the highest levels showed the greatest decline in production. The two treatment levels showing the greatest increases were 67-67-134 and 67-134-67 kg./ha. The third treatment, 67-67-67 kg./ha., illustrates well the objective of this study, an application of twice as much of each nutrient failed to raise production significantly. That is to say, the 67-134-67 and 67-67-134 kg./ha. treatments although twice as large, and expensive as the 67-67-67 kg./ha. treatment did not increase production by a statistically significant amount.

A possible explanation for the lower yields in the other four treatments would be lack of uniformity of maturity. The cabbages were harvested when approximately

10 percent of the heads were bursting the outer wrapper leaves. Since maturity lacked uniformity, many heads were smaller than normal at harvest. Those treatments showing high yields were more uniform in size at the time of harvest.

Lima and Snap Bean Yields

The lima and snap bean treatments showed no response at any location or between years at the Knoxville location (Tables 9, 10, and 11, Appendix). This is not surprising as soil tests showed very high P and K levels. The P levels after the first year were, for the most part, off scale on the high end. The K levels ranged between 336 and 672 kg./ha. in the soil at the end of the first year. Jenkins (10) reported an average crop of snap beans removed only from 36 to 45 kg./ha. of K. It is evident, therefore, that it will be several years before K, at least, is removed to the point where it would become limiting. The high levels of P lead to similar speculations.

1975 and 1976 Yields of Tomatoes at Knoxville

When yields obtained in 1975 are compared to 1976 (Tables 1, and 4, Appendix), at the Knoxville location only, total production as a whole is down. Average total production of marketable fruit in 1975 surpassed 1976 by 14.3 kg./ha. Fruit size on the other hand, was greater in 1976 with the average fruit for that year weighing 23 grams more than the average 1975 fruit. Cool weather delayed

plant growth in 1976 so the first fruits were picked nearly three weeks later in the season than the previous year. As a result earliness and weight of early yield cannot be objectively compared.

Tissue Analysis of Cabbage

When N was applied to the cabbage plots at the first increment, from treatment 1 (0-0-0 kg./ha.) to treatment 2 (67-0-0 kg./ha.) a significant rise in NO_3^- -N and a decrease in P content of the petioles occurred (Table 12, Appendix). No corresponding changes were observed for the K and NH_4^+ -N fractions. When N was increased from treatment 7 (67-134-134 kg./ha.) to treatment 6 (134-134-134 kg./ha.) there was a corresponding increase in both NO_3^- -N and P. A possible explanation for the difference in P absorption at the two rates might be the overall growth and vigor of the plants grown under the higher fertilizer regime. (Between treatments 1 and 2 the initial increments of P and K had not been applied but both elements are present in 134 kg./ha. amounts in both treatments 6 and 7.)

Where P was the varied element a significant rise in the P content of the petioles was noted (Table 12, Appendix). However this rise was obvious only at the Knoxville location.

An increase in NH_4^+ -N content was noted when P and K were introduced between treatments 2 (67-0-0 kg./ha.) and 3 (67-67-67 kg./ha.) at the Crossville location (Table 12, Appendix). Improved root growth is associated with P

fertility which may explain the increased NH_4^+N content due to improved foraging ability.

The cabbage tissue samples from Knoxville and Crossville were the only ones to show significant differences in nutrient content (Tables 14 and 15, Appendix).

IV. SUMMARY

Soil tests before and after each crop season indicate very high levels of P and K in the soil, (soil test results were only available for the Knoxville location). This condition will make it necessary for the experiment to be carried further towards the completion date before it can be determined at what residual fertility level additional P and K applications will result in a significant return. It is clear, however, cabbage will respond well to relatively high levels of N, P and K, the greatest response being to N. Growers with fields testing high in P and K may, therefore, find no significant decrease in yield should they restrict P and K fertilization in favor of more responsive N fertilization.

Analysis of the first year Knoxville data indicate tomatoes will respond to P and K even where the soils test high in those elements. This observation is inconclusive though, as plots receiving no fertilizer whatsoever, in two years performed so well in the second year as to not be significantly different from those receiving the highest levels of fertilization.

The nutrient requirements of lima and snap beans are so small that no significant differences could be discerned at any location. Perhaps the yields from the lower testing Jackson soils may soon begin to fall off as the residual

soil levels of P and K become more depleted. In any case heavy fertilization of a crop of lima beans is useless as greater differences are seen from year to year than are evident from one fertilization rate to another. Snap beans too, require less fertilizer than the high testing soils of the test plots could supply and showed no response to additional applications.

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APPENDIX

TABLE 1
COMPARISON OF 1975 TOMATO YIELDS
AND AVERAGE FRUIT SIZE FROM DIFFERENT FERTILIZER RATES
AT THE KNOXVILLE LOCATION

Treatment Number	N-P ₂ O ₅ -K ₂ O (Kg./Ha.)	Average		Early	Yield of Tomatoes	
		Fruit Size (Gms.)	Fruit Size		Total Marketable	Total All Grades
1	0-0-0	179		27.3	39.0	53.6
2	67-0-0	213		43.0	57.8	78.3
3	67-67-67	222		38.4	53.1	72.1
4	67-67-134	204		47.9	59.1	81.5
5	67-134-67	205		41.0	50.9	72.8
6	134-134-134	205		44.2	56.6	78.7
7	67-134-134	202		39.3	53.3	77.9
L. S. D. @ .01		27		11.2	12.4	12.8

TABLE 2

COMPARISON OF 1975 TOMATO YIELDS
AND AVERAGE FRUIT SIZE FROM DIFFERENT FERTILIZER RATES
AT THE CROSSVILLE LOCATION

Treatment Number	N-P ₂ O ₅ -K ₂ O (Kg./Ha.)	Average		Yield of Tomatoes		
		Fruit Size (Gms.)	Early	Total Marketable	-(MT/Ha.)	Total All Grades
1	0-0-0	153	9.7	20.4		23.0
2	67-0-0	148	11.7	27.2		29.3
3	67-67-67	168	16.8	36.2		39.4
4	67-67-134	163	17.8	36.1		41.8
5	67-134-67	170	20.5	37.0		42.0
6	134-134-134	162	18.8	36.7		39.8
7	67-134-134	171	19.5	39.0		43.8
L. S. D. @ .01		N.S.	8.0	12.8		13.2

TABLE 3
COMPARISON OF 1975 TOMATO YIELDS
AND AVERAGE FRUIT SIZE FROM DIFFERENT FERTILIZER RATES
AT THE JACKSON LOCATION

Treatment Number	N-P ₂ O ₅ -K ₂ O (Kg./Ha.)	Average Fruit Size (Gms.)	Early	Total Marketable -- -- -- -- (MT/Ha.)	Total All Grades
1	0-0-0	178	12.1	71.5	81.3
2	67-0-0	175	13.2	86.8	96.3
3	67-67-67	175	20.2	94.3	104.0
4	67-67-134	186	17.3	98.1	109.2
5	67-134-67	188	16.8	99.7	114.2
6	134-134-134	186	18.1	95.5	108.1
7	67-134-134	184	15.4	105.4	116.6
L. S. D. @ .01		N.S.	N.S.	N.S.	N.S.

TABLE 4

COMPARISON OF 1976 TOMATO YIELDS
AND AVERAGE FRUIT SIZE FROM DIFFERENT FERTILIZER RATES
AT THE KNOXVILLE LOCATION

Treatment Number	N-P ₂ O ₅ -K ₂ O (Kg./Ha.)	Average		Yield of Tomatoes		
		Fruit Size (Gms.)	Early	Total Marketable	Total All Grades	
1	0-0-0	213	29.2	45.8	58.1	
2	67-0-0	220	29.4	48.6	58.0	
3	67-67-67	223	35.8	52.4	63.9	
4	67-67-134	226	34.2	50.1	64.2	
5	67-134-67	244	37.8	57.0	74.7	
6	134-134-134	235	33.8	57.0	76.1	
7	67-134-134	227	42.3	58.8	72.1	
L. S. D. @ .01		N.S.	9.6	N.S.	N.S.	

TABLE 5
COMPARISON OF 1975 CABBAGE YIELDS AND AVERAGE WEIGHT
OF MARKETABLE HEADS FROM DIFFERENT FERTILIZER RATES
AT THE KNOXVILLE LOCATION

Treatment Number	N-P ₂ O ₅ -K ₂ O (Kg./Ha.)	Average Head Weight (Kgs.)	Yield of Cabbage (MT/Ha.)
1	0-0-0	1.05	39.4
2	67-0-0	1.86	69.3
3	67-67-67	1.50	56.1
4	67-67-134	1.72	64.3
5	67-134-67	1.54	57.7
6	134-134-134	2.26	83.0
7	67-134-134	1.80	67.1
L. S. D. @ .01		.44	16.0

TABLE 6

COMPARISON OF 1975 CABBAGE YIELDS AND AVERAGE WEIGHT
OF MARKETABLE HEADS FROM DIFFERENT FERTILIZER RATES
AT THE JACKSON LOCATION

Treatment Number	N-P ₂ O ₅ -K ₂ O (Kg./Ha.)	Average Head Weight (Kgs.)	Yield of Cabbage (MT/Ha.)
1	0-0-0	.98	36.6
2	67-0-0	1.32	49.4
3	67-67-67	1.66	62.0
4	67-67-134	1.67	62.4
5	67-134-67	1.89	70.4
6	134-134-134	2.06	76.5
7	67-134-134	1.86	69.6
L. S. D. @ .01		.45	16.8

TABLE 7

COMPARISON OF 1975 CABBAGE YIELDS, AVERAGE WEIGHT
OF MARKETABLE HEADS AND SNAP BEAN YIELDS
FROM DIFFERENT FERTILIZER RATES
AT THE CROSSVILLE LOCATION

Treatment Number	N-P ₂ O ₅ -K ₂ O (Kg./Ha.)	Average Head Weight (Kgs.)	Yield of Cabbage - - - - (MT/Ha.)	Yield of Snap Beans - - - -
1	0-0-0	.47	4.9	5.5
2	67-0-0	.49	9.9	6.3
3	67-67-67	1.27	26.8	5.5
4	67-67-134	1.02	18.9	4.9
5	67-134-67	1.12	18.6	6.6
6	134-134-134	1.14	24.3	5.4
7	67-134-134	.82	14.7	5.5
L. S. D. @ .01		.61	14.0	N.S.

TABLE 8

COMPARISON OF 1976 CABBAGE YIELDS AND AVERAGE WEIGHT
OF MARKETABLE HEADS FROM DIFFERENT FERTILIZER RATES
AT THE KNOXVILLE LOCATION

Treatment Number	N-P ₂ O ₅ -K ₂ O (Kg./Ha.)	Average Head Weight (Kgs.)	Yield of Cabbage (MT/Ha.)
1	0-0-0	.98	36.8
2	67-0-0	1.42	52.9
3	67-67-67	1.67	62.5
4	67-67-134	2.13	79.6
5	67-134-67	1.90	70.9
6	134-134-134	1.70	63.5
7	67-134-134	1.56	58.2
L. S. D. @ .01		.46	17.1

TABLE 9
COMPARISON OF 1975 LIMA BEAN YIELDS
AND PERCENT SHELL OUT FROM DIFFERENT FERTILIZER RATES
AT THE KNOXVILLE LOCATION

Treatment Number	N-P ₂ O ₅ -K ₂ O (Kg./Ha.)	Yield of Lima Beans		Percent Shell Out
		Total	Shelled	
		- - - - (MT/Ha.)	- - - -	
1	0-0-0	6.5	2.6	41
2	67-0-0	7.2	2.9	40
3	67-67-67	6.9	2.8	40
4	67-67-134	7.3	2.9	40
5	67-134-67	7.3	2.9	39
6	134-134-134	7.2	2.9	40
7	67-134-134	7.1	2.6	37
L. S. D. @ .01		N.S.	N.S.	N.S.

TABLE 10
COMPARISON OF 1976 LIMA BEAN YIELDS
AND PERCENT SHELL OUT FROM DIFFERENT FERTILIZER RATES
AT THE KNOXVILLE LOCATION

Treatment Number	N-P ₂ O ₅ -K ₂ O (Kg./Ha.)	Yield of Lima Beans		Percent Shell Out
		Total	Shelled	
		- - - - (MT/Ha.)	- - - -	
1	0-0-0	6.2	3.3	43
2	67-0-0	6.0	3.5	46
3	67-67-67	7.0	3.8	50
4	67-67-134	8.2	3.6	47
5	67-134-67	7.8	3.7	48
6	134-134-134	8.1	3.5	48
7	67-134-134	8.1	3.6	48
L. S. D. @ .01		N.S.	N.S.	N.S.

TABLE 11
COMPARISON OF 1975 LIMA BEAN YIELDS
AND PERCENT SHELL OUT FROM DIFFERENT FERTILIZER RATES
AT THE JACKSON LOCATION

Treatment Number	N-P ₂ O ₅ -K ₂ O (Kg./Ha.)	Yield of Lima Beans		Percent Shell Out
		Total	Shelled	
		- - - - (MT/Ha.)	- - - -	
1	0-0-0	2.5	6.0	42
2	67-0-0	2.6	5.8	44
3	67-67-67	2.5	5.9	43
4	67-67-134	2.3	5.3	44
5	67-134-67	2.6	6.1	43
6	134-134-134	2.3	5.4	42
7	67-134-134	2.7	6.2	44
L. S. D. @ .01		N.S.	N.S.	N.S.

TABLE 12
COMPARISON OF 1975 NUTRIENT CONTENTS OF TISSUE SAMPLES
ON A DRY WEIGHT BASIS FROM CABBAGE GROWN
AT DIFFERENT FERTILIZER RATES
AT THE KNOXVILLE LOCATION

Treatment Number	N-P ₂ O ₅ -K ₂ O (Kg. /Ha.)	P	K	NH ₄ ⁺ N	NO ₃ ⁻ N
		---	%	---	ppm
1	0-0-0	.22	3.75	1.66	27
2	67-0-0	.13	3.68	1.86	72
3	67-67-67	.16	4.42	2.16	69
4	67-67-134	.16	4.98	1.97	73
5	67-134-67	.20	4.05	2.22	73
6	134-134-134	.18	4.52	2.34	109
7	67-134-134	.19	4.85	2.20	68
L. S. D. @ .01		.04	N.S.	N.S.	19

TABLE 13

COMPARISON OF 1975 NUTRIENT CONTENTS OF TISSUE SAMPLES
ON A DRY WEIGHT BASIS FROM CABBAGE GROWN
AT DIFFERENT FERTILIZER RATES
AT THE CROSSVILLE LOCATION

Treatment Number	N-P ₂ O ₅ -K ₂ O (Kg./Ha.)	P	K	NH ₄ ⁺ N	NO ₃ ⁻ N
		- - - - -	% - - - - -	- - - - -	ppm
1	0-0-0	.11	4.10	1.72	53
2	67-0-0	.15	3.61	2.43	67
3	67-67-67	.15	3.40	1.44	39
4	67-67-134	.14	3.58	1.44	34
5	67-134-67	.16	3.39	1.42	30
6	134-134-134	.16	3.79	1.83	72
7	67-134-134	.17	3.39	1.12	23
L. S. D. @ .01		N.S.	N.S.	.86	31

TABLE 14

COMPARISON OF 1975 NUTRIENT CONTENTS OF TISSUE SAMPLES
ON A DRY WEIGHT BASIS FROM TOMATOES
GROWN AT DIFFERENT FERTILIZER RATES
AT THE KNOXVILLE LOCATION

Treatment Number	N-P ₂ O ₅ -K ₂ O (Kg./Ha.)	P	K	NH ₄ ⁺ N	NO ₃ ⁻ N
		- - - - -	% - - - - -	- - - - -	ppm
1	0-0-0	.23	2.00	3.48	8
2	67-0-0	.22	2.08	4.00	13
3	67-67-67	.23	2.18	3.76	11
4	67-67-134	.24	2.35	3.60	10
5	67-134-67	.24	2.15	3.49	8
6	134-134-134	.26	2.15	3.82	16
7	67-134-134	.21	2.12	3.80	9
L. S. D. @ .01		N.S.	N.S.	N.S.	N.S.

TABLE 15
COMPARISON OF 1975 NUTRIENT CONTENTS OF TISSUE SAMPLES
ON A DRY WEIGHT BASIS FROM LIMA BEANS
GROWN AT DIFFERENT FERTILIZER RATES
AT THE KNOXVILLE LOCATION

Treatment Number	N-P ₂ O ₅ -K ₂ O (Kg. /Ha.)	P	K	NH ₄ ⁺ N	NO ₃ ⁻ N ppm
		- - - - -	% - - - - -	- - - - -	
1	0-0-0	.14	1.74	1.53	7
2	67-0-0	.16	1.83	1.69	10
3	67-67-67	.15	1.71	1.63	8
4	67-67-134	.14	1.77	1.56	10
5	67-134-67	.16	1.96	1.56	12
6	134-134-134	.13	1.60	1.77	13
7	67-134-134	.14	1.62	1.60	9
L. S. D. @ .01		N.S.	N.S.	N.S.	N.S.

VITA

Shannon Loriece Morris was born in Lexington, Kentucky on June 29, 1947. He attended elementary and high schools across the country as his military father changed assignments. In June, 1966, he was graduated from Clover Park High School in Tacoma, Washington and began a four year tour of duty with the United States Navy.

He attended Austin Peay State University of Clarksville, Tennessee from January, 1971 to August, 1974, when he received a Bachelor of Science degree in General Agriculture. In the fall of 1974 he accepted a research assistantship at the University of Tennessee, at Knoxville, and received a Master's degree in Plant and Soil Science in August, 1980.

The author is a member of Delta Tau Alpha, Alpha Gamma Rho, and Corinth Baptist Church in Dover, Tennessee. After graduation he will continue operating the farm he owns with his wife, the former Myra Paulette Earhart of Dover, Tennessee. The farm is also the home of their two children, Tiffany Rae Morris, aged six and Jonathan Daniel Morris, aged three.