12-1983

# Sequential cropping of vegetables on black plastic using two sources and rates of nitrogen fertilizers

Philip William Ramsey

To the Graduate Council:

I am submitting herewith a thesis written by Philip William Ramsey entitled "Sequential cropping of vegetables on black plastic using two sources and rates of nitrogen fertilizers." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant, Soil and Environmental Sciences.

David L. Coffey, Major Professor

We have read this thesis and recommend its acceptance:

Alvin Rutledge, Gary lessman

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Accepted for the Council:

Cwminkel

The Graduate School

# SEQUENTIAL CROPPING OF VEGETABLES ON BLACK PLASTIC USING TWO SOURCES AND RATES OF NITROGEN FERTILIZERS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Philip William Ramsey

December 1983

## ACKNOWLEDGMENTS

The author wishes to express his sincere gratitude and appreciation to those who gave advice, encouragement, and assistance during the course of this project:

The University of Tennessee and Dr. Lloyd Seatz for supplying the facilities and financial support for this study.

Dr. David L. Coffey for his friendship, guidance, and continued assistance throughout the completion of this thesis.

Dr. Alvin Rutledge and Dr. Gary Lessman for serving on the author's committee and for their continued support and guidance.

John E. Willingham, Jr. for his supervision, assistance, and friendship during his work and study at The University of Tennessee.

David Hooten for his assistance and friendship in academic and field work.

Mahdi Abdal for his assistance and friendship in academic and field work.

Carolyn Drake, Martha Cox, and Paula Dalton for their work beyond the call of duty in typing this thesis.

Mr. and Mrs. Grady L. Ramsey, the author's parents, for their love, support, and encouragement.

Shelley Ramsey, the author's wife, for her love, support, encouragement, and patience during his graduate study and manuscript preparation.

Jesus Christ, for without Him the author could do nothing.

## ABSTRACT

Broccoli (Brassica oleracea), bell peppers (Capsicum annum var. annum grossom group), yellow summer squash (Cucurbita pepo var. melopepo), and tomatoes (Lycopersicon esculentum) were grown on an Etowah fine loamy soil during the seasons of 1982-1983 as single or double crops on black polyethylene film mulch at the Plant and Soil Science Field Laboratory, Knoxville, TN in order to compare the relative projected gross returns of each crop and crop sequence and to compare two different sources (urea and sulphur-coated urea) and rates (145 and 290 kg/ha) of nitrogenous fertilizers. The fertilizer was banded and incorporated beneath black plastic rows at the beginning of each growing season. Yields by grade were taken of each crop and wholesale prices were recorded at the end of each harvest. The recorded prices provided a common denominator of monetary value in order to compare estimated returns from the crops and cropping sequence.

During both years tomatoes were significantly higher in projected gross returns than all other crops and cropping sequences. The double crops of broccoli-pepper and broccoli-squash were not significantly different from each other in gross returns. The double crop of broccoli-pepper did not give significantly different gross returns than the single crop of broccoli in 1982 or 1983. The double crop of broccoli-squash was not significantly different in value than the single crop of broccoli in 1982 but did give

higher gross returns in 1983. All other single crops with the exception of tomatoes were not significantly different in returns in 1982, yet were different in 1983.

There were no significant differences in projected gross returns between fertilizer treatments on single crops and cropping sequences either year except on the broccoli crop during 1982. The high rate of urea allowed broccoli to have significantly higher returns than from the other fertilizer treatments.

During both years of the study, yields of most single crops were not influenced by various nitrogen fertilizer treatments, except broccoli which was significantly increased as a result of the high rate of urea. Marketable yields of squash following broccoli and U.S. Fancy grade peppers following broccoli also increased as a result of a higher application rate of sulphur-coated urea.

The first crop planted in a double crop sequence demonstrated greater yields and projected gross returns than the second crop both years.

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CHAPTER I

# INTRODUCTION

Conventional cropping includes the practice of growing a single crop during a growing season. For years vegetable farmers have been reaping sufficient returns from this system. Recently there has been a tremendous increase in the cost of production for every vegetable crop. Therefore, the conventional one-crop-per-season practice is being replaced by more intensive multiple cropping culture (35). Sequential cropping is a multiple cropping system that involves growing two or more crops in a sequence on the same unit area of land per year. After each crop is harvested, a succeeding crop is planted. This allows fixed costs to be distributed over two or more crops which increases the amount of return per dollar invested (3,15,34). The aim of sequential cropping is to maximize total production and returns per unit area of land. This is accomplished by growing high yielding compatible crop sequences. By accomplishing this aim a farmer can multiply his net return per unit area of land. Sequential cropping is only possible when the duration of the growing season allows the complete growth and production of more than one crop (3,35).

Intensive cropping requires an adequate supply of moisture and nutrients throughout the growing season. Black plastic mulch helps meet these requirements. Black plastic mulch conserves soil moistures, increases soil temperature, and reduces weed growth in

the plant row. It also reduces the occurrence of certain disease, enhances cleanliness of produce, and provides a means for such practices as trickle irrigation and soil fumigation (27). Black plastic mulching has several benefits for intensive culture of vegetable crops, but it impedes midseason sidedressing of nitrogenous fertilizer due to the physical barrier of the plastic. As a result, second and third crops have shown nitrogen deficiencies (42) and depressed yield during the growing season. Because of the plastic mulch additional nitrogen cannot be supplied to the plant during critical mid-season growth periods. Research on sequential cropping on black plastic which was conducted at the University of Tennessee Experiment Station, Knoxville, in 1981 demonstrated the decline in plant performance with double and triple crops as the growing season progressed.

The research reported here basically has two objectives. The first objective is to determine which cropping sequence yields the greatest economic value. The second objective is to compare the performance of two different formulations of nitrogen fertilizers (urea and sulphur-coated urea) and two different nitrogen fertilizer rates (145 and 290 kg/ha) applied beneath the row under the black plastic.

# CHAPTER II

# LITERATURE REVIEW

## Black Plastic Mulch

Mulching of vegetable crops with black polyethylene (plastic) film improves production significantly. Vegetable production is improved with black plastic mulching by increasing yields, by shortening maturity dates for earlier harvests, and by increasing size and improving quality of some vegetable crops. The yield of several vegetable species (i.e., watermelons, peppers, tomatoes, lettuce, summer squash) has been significantly increased by black plastic mulching (1,10,11,18,20,24,27,29,44,57,60) as well as enhancing early harvest of several vegetable crops (1,4,10,24,27,57, 60). In many cases the size of the fruit has increased with plastic mulching. Experiments have also revealed that the fruit and head size of vegetables such as watermelons, bell peppers, and lettuce have increased when grown on plastic (1,20,60). Size is of significant market importance with these vegetables. Plastic mulching also improves fruiting quality (16,23,34). Halsey (23) discovered that the plastic prevented soil abrasions on tomatoes which increased fruit decay caused by soil borne pathogens. Schales and Sheldrake (57) tested plastic mulch effects on muskmelons and found that there was less occurrence of fruit rot with mulch treatments and the fruit was also cleaner (free from soil debris) than with conventional culture.

The improvement of vegetable crop production from the application of black plastic mulch is a result of several microclimatic changes in the soil and at the soil surface. Black plastic mulch conserves and improves soil fertility (1,5,8,9,10,11,16,20,33,36,44). Albregts and Howard (1) discovered that soils treated with this mulch caused an increase in nitrate and potassium residual levels. Courter (11), Liptay (36), and Black (5) found an increased accumulation of nitrates in surface soils mulched with this material. Black attributed this accumulation to the increased temperatures under plastic leading to an increase in populations of nitrifying bacteria. Not only does the nitrates accumulate in surface soils under plastic, but also they are conserved by reduced leaching (1,10,16,33,36,60). Bryan and Dalton (8) cited that the use of black plastic would be an appropriate cultural practice for multiple cropping due to the nutrient conserving capacity of the surface soil under plastic.

Black plastic mulch also maintains and improves physical properties of the soil. It significantly raises the soil temperature (5,11,24,36,44,57) which is especially beneficial for earlier germination of seed and seedling growth in the spring months. Mooreman (44) found increases in surface soil temperature 5 cm. deep. Black and Greb (5) found the temperature of the soil to be elevated 3-7°F higher under black plastic than in non-mulched soils. It was found to reduce the diurnal fluctuations of the soil temperature (10,24,29,61). Takatoric and Lippert (61) cited that pockets of air between the mulch layer and the soil inhibit the conduction of heat

into the soil during the day, yet aids in retaining soil heat during the night.

Plastic mulch also conserves soil moisture (4,5,9,11,16,24, 26,29,36,57). Hopen (29) tested its effects on soil temperature and sweet corn growth and discovered that soil water content was retained longer under plastic mulch after precipitation than was retained with no mulch. Schales and Sheldrake (57) tested mulch effects on soil conditions and muskmelon yield response and found that at various times during the season the surface soil section in the middle of the plastic row was deficient in water content, but the lower root zone was not deficient. This differed to the deficiency of water in the lower root zone of non-mulched soils. Liptay and Tiessan (36) cited that mulching conserved soil moisture due to the prevention of soil evaporation. Army and Hudspeth (4) agreed with this concept claiming that soil evaporation under mulching condenses on the lower side of the black plastic row and is conserved. However, they state that moisture is also increased in the soil surface under plastic by the mechanism of upward capillary water movement during the night. This is caused by temperature gradients from the warmer lower soil depths to the cooled soil surface.

Black plastic mulch prevents soil compaction which allows a lower bulk density and better aeration of the soil under the row which provides conditions for better root growth (11,16,36,57).

Plastic mulching improves the atmospheric environment immediately above the soil surface. Clarkson (10) cites that the

influence of climatic variations at the soil surface is minimized due to the build-up of blocked reradiation from the soil by the plastic mulch barrier. This heat build-up at the soil surface may have a positive effect on frost damage protection. However, he believes that if a sufficient amount of the heat does not reach the plant then this phenomenon may be conversely detrimental to the plant with regard to frost protection. Yet, Harris (24) verifies that the atmospheric temperature immediately above the soil surface increases and, thus, provides a beneficial environment for plant growth in the early spring.

Polyethylene mulching also improves the surface environment for crops by increasing carbon dioxide concentration around the immediate microclimate of the plant (11,29,56).

Enhancing the biological properties of the soil by increasing the number of soil microbes is another favorable effect. Black and Greb (5) cite that the higher temperature and moisture conditions created by polyethylene mulching favor a higher microbial population. Among the increased microbial population will be beneficial nitrifying bacteria genera such as *Nitrosomonas*, *Nitrosolabus*, *Nitrobacter*, and *Nitrosospira* (43). An increase in these bacteria genera results in an accumulation of nitrates.

Black plastic mulching helps control several pests. Most weed species that germinate under the plastic row are eliminated due to the restriction of sunlight to weed seedlings (9,11,16,27). Plastic mulching also prevents the incidence of fruit rot diseases such as buck-eye rot or soil rot on tomatoes.

Other benefits include the feasibility of utilizing additional beneficial cultural practices. One of these practices includes the use of trickle irrigation underneath the polyethylene film row. Trickle irrigation improves the fertilizer efficiency when it is placed under plastic mulching (50). For example, Csizinsky and Overman (13) found that broccoli yields were significantly increased by the use of trickle irrigation underneath plastic.

Another cultural practice which can be utilized with plastic mulching is soil fumigation for the elimination of pests (i.e., weed seed viability, soil borne insects and diseases, and nematodes) (63).

Only two disadvantages of black plastic mulching are cited. Along with the increased microbial population, harmful soil borne pathogens may also increase. Mooreman (44) cites that the elevation of soil temperature under plastic causes optimum conditions for Verticillium wilt infection unless accompanied by fumigation. He also cited that mulched eggplants developed wilt disease symptoms 7-10 days earlier than non-mulched plants.

Another possible disadvantage of plastic is injury to transplants set in the summer months. Clarkson (10) found that surface or microclimate temperatures immediately above the mulched row were 20-25°F higher than those above non-mulched rows. He claimed that these high temperature conditions may cause injury to newly set transplants or inhibit seed germination.

The energy consumption and productivity of black polyethylene mulch have been evaluated by Shaw and Everett (58) for tomato production. Energy consumption is increased due to the energy invested in the application, soil fumigation, increased fertilization and increased irrigation. Yet, there are decreases in energy consumption with mulching due to fewer cultivations and elimination of the need for a pre-emergence herbicide. They claim that the net energy consumption with mulching gave a net 50 percent increase per unit area in total energy requirements for production and harvesting as opposed to not using a mulch. However, since plastic mulching results in greater production, the quantity of product per unit of energy (energy productivity) is slightly increased. Bryan and Dalton (8) state that double cropping on polyethylene mulching greatly increases energy efficiency because of extended use of production inputs. Everett (19) also states that energy consumption is increased only slightly with a double crop over that of a single crop. Input costs for a double crop were 70-75 percent lower than those for a single crop.

Black polyethylene serves as a substitute for nitrogenous sidedressing or slow release fertilization (18,41) for single crops. Locascio and Fiskell (39) discovered that watermelon yield response was the same for treatments of broadcasted urea under plastic mulching compared to treatments using SCU slow release fertilizer as a single application or for treatments using urea or ammonium nitrate in three split applications without plastic mulching.

In another experiment Locascio and Fiskell (41) found that bell pepper yield response from urea applied under black plastic surpassed yield response from non-mulched treatments of three split urea applications or a single application of sulphur coated urea. It is evident that non-mulched crops require more nitrogen fertilization than mulched crops. As a result of a two-year experiment on tomato production, Jones et al. (33) found that non-mulched crops require more nitrogen than mulched crops. They found that tomatoes require over twice the amount of nitrogen fertilizer to approach the yield margin resulting from mulched plots. They discovered that the highest yield of 29.8 MT/ha was produced with the application of 60 kg/ha of nitrogen on mulched plots, and the highest yield of tomatoes without mulch (25.6 MT/ha) required 138 kg/ha of nitrogen.

The application of different fertilizer rates under mulch does not normally result in significant yield differences. Everett (20) found that the effect of varying fertilizer rates of 420, 700, or 920 lbs/acre of 18-0-25 fertilizer under mulch had no significant effect on the yield and individual head weight of lettuce. Csizinsky and Overman (13) also found that varying fertilizer rates of Osmocote 14-14-14 at 1,131 kg/ha and Osmocote 14-14-14 at 1,131 kg/ha + $KNO_3$ at 336 kg/ha under mulch had no significant effect on the yield of broccoli and cauliflower, even with the addition of trickle irrigation. However, in an experiment on tomatoes (17) Everett found that yields were significantly lower with the high

fertilizer rates in comparison with low or medium fertilizer rates. In a later experiment (18) Everett found that in the third and fourth year of mulch grown staked tomatoes, the yields and size were lower from the higher rates of nitrogen and potassium fertilization.

The method of fertilizer application under polyethylene mulching may or may not have a definite effect on double crop performance and efficiency. Bryan and Dalton (8) discovered that incorporation of fertilizer under mulching resulted in higher yields of tomatoes and a second crop of butternut squash than resulted from not incorporating fertilizer. They found that low fertilizer rates incorporated gave equal production to that of high fertilizer rates that were not incorporated. Everett (19) conducted a fertilization experiment for tomatoes with cucumbers as a second crop. Fertilizer was drilled into the plastic mulch at different distances and depths from the plant. He found that fertilizer depths or distances from the plant gave no significant yield differences. Hayslip, Mishoe (26), and Myres and Locascio (46) experimented with a tractor-mounted square-bar applicator that applies fumigation and also supplementary fertilizer via a plug mix planter. They found that double crops of tomatoes and cucumbers responded with a 79 percent increase in yield with the supplementary fertilizer added via the plug-mix in comparison to only preplant fertilizer applications.

<u>Sequential Cropping</u>

Multiple cropping is not a recent practice since it was found recorded in Egypt around 300 B.C. Evidence of multiple cropping was

also recorded in Babylon by Pliny in 77 A.D. and was recorded in Iran during the Islamic conquest from the 7th to the 11th centuries. At that time four crops per year were being produced under irrigation (28). Yet, not until recently has multiple or sequential cropping become of serious interest to the horticultural community. The recent interest has increased because of the high initial costs of polyethylene mulch, soil fumigation, and irrigation practices (34).

There are several advantages of sequential cropping. First, there is increased profit potential due to a greater production per unit area of land. Second, sequential cropping allows more production per acre and thus eliminates the need to utilize additional acres for the same magnitude of production. Third, there is more efficient use of moisture, sunlight, fertilizer, fumigation, mulching, labor, capital, etc. Fourth, sequential cropping creates greater probability of success and less risk for the farmer with more than one crop to rely upon for production and profit (3,15,19).

Sequential cropping encounters four basic disadvantages. First there is the problem of insufficient residual nutrients after the first crop. Mandal et al. (42) discovered that multiple cropping depletes soil nutrients which can be attributed to crop removal and eventual leaching. Prasach and Singh (51) found that even if high rates of N-P-K fertilizer are applied initially, that exchangeable calcium and magnesium decrease. Second, continued use of polyethylene mulch with sequential cropping allows a build-up of

soil-borne pathogens and nematodes. Third, plastic mulching for double crops presents the disadvantage of removal of plastic from the field after the growing season ends (1). Fourth, with intensive land use there must be intensive management measures which must provide for the efficient use of machinery, labor, and capital investment (19,34,35). Nonetheless, with present advances in sequential cropping these problems are being solved (26,34,46). For example, Kays et al. (34) cite that problems with nematodes and soil-borne pathogens encountered with the double cropping of pepper and squash can be adequately controlled by fumigation. Fertilizer applicators developed in Florida for double crops eliminate the problem of sufficient crop nutrition (26). Biodegradeable plastic mulches are being developed to eliminate the need for removal of plastic mulching at the end of the growing season (1).

The practice of sequential cropping involves several management requirements and cultural considerations. Fertilizer applications should be made to either coincide with or precede periods of nutrient uptake and rapid growth of the crop (48). Cropping patterns must also be adapted to the available conditions (i.e., climate, water availability, pest population, machinery, etc.) (48). Finally, the cropping sequence should be compatible with a rotation that encourages natural pest control (37).

Sequential cropping involves other considerations of importance. Amounts and rates of nutrient uptake vary differently among crop species. Oelsligle (48) cites such variations in tropical

multiple cropping. The amount of nutrients a given crop requires for production is valuable information which can be useful in designing fertilization practices for a sequential cropping system. Rates of nutrient uptake are valuable, yet uptake rates vary with plant age and crop species. Consideration should be given towards the knowledge of bench-mark data on total nutrient demand and nutrient removal of each crop and also, rates of nutrient accumulation of the soil and crop. However, it is important to note that the estimated returns of the cropping sequences should be recorded simultaneously with the biological yield (48) when considerations are made for fertilization practices.

## Urea

Nitrogen (N) is one of the most important nutrients attributed to crop production. Therefore, nitrogen fertilization is critical for balancing nutrient loss from the soil caused by such things as crop removal, leaching, volatilization, and denitrification (43).

Urea $CO(NH_2)_2$ has become a leading nitrogen fertilizer throughout the world and has surpassed ammonium nitrate in popularity (43,45). Urea (46%N) at first was produced as fragile prills that were cooled and solidified droplets of concentrated solution as they passed through cool air in a prill tower. As the popularity of bulk blending increased, urea was produced into larger granules. The manufacture of these larger urea granules

was piloted by the Tennessee Valley Authority, National Fertilizer Development Center, Muscle Shoals, Alabama. Studies were initiated with the aim of producing urea with a pan granulator (45). By 1976, urea became the lowest costing fertilizer with the exception of ammonium nitrate (21).

Application of urea to the soil is followed by subsequent chemical reactions. Upon application, urea is split by the enzyme urease and hydrolyzed into products of ammonium ($NH^+{}_4$) and carbon dioxide ($CO_2$) (43). Daif and Beusichem (14) have found that in light textured soils, urease activity and subsequent urea hydrolysis is inhibited 7-20 percent when iron, copper, and zinc compounds are applied at 20 mg $g^{-1}$ of soil. These heavy metal ions also inhibit ammonia evolution from the soil.

The resulting $NH_4^+$ from urea hydrolysis is either taken up by plant roots or soil microorganisms, adsorbed or fixed to soil particles, or oxidized to nitrate ($NO_3^-$). Consequently, fertilizer N that is incorporated into organic soil N is released from organic matter through mineralization. Mineralization of organic N increases with relatively low carbon to nitrogen ratios and high soil moisture and soil temperatures (43).

Plant uptake of $NH_4^+$ is slower than uptake of $NO_3^-$ because the $NH_4^+$ ions tend to adsorb onto negatively charged clay minerals (i.e., illites, vermiculites, and montmorillonites). The uptake of $NH_4^+$ is increased in cooler temperatures and in neutral soil pH's while the uptake of $NO_3^-$ is more rapid at lower soil pH's.

Nonetheless, in most cases the final total yield responses of crops are not significantly different due to the eventual uptake of either $NH_4^+$ or $NO_3^-$ (43).

Soil N is lost from the plant by means of $NH_3$ volatilization, denitrification, and leaching. Several factors influence $NH_3$ volatilization from the soil. As soil temperature, moisture, and pH increases, $NH_3$ volatilization increases. As depth of urea placement increases, volatilization decreases (55). For example, Samuels (55) and Savant et al. (56) found that deeper incorporation of urea granules resulted in greater plant use efficiency. According to Samuels, incorporation of urea at depths of 3.81 cm. as opposed to surface application reduced N-loss by 11 percent, and urea placement at 6.35 cm. resulted in the total elimination of $NH_3$ volatilization.

Urea-N is also eventually lost by denitrification after hydrolysis and nitrification processes. Nitrate fertilizers undergo denitrification faster than ammonium fertilizer. Nitrates are denitrified under anaerobic conditions, in high organic soils, and in soils that are high in temperature (43,55). Thus, since urea is not a nitrate fertilizer, it is a more efficient fertilizer when applied to soil under such conditions.

Urea-N is also eventually lost by leaching after it is converted to $NH_4^+$ and $NO_3^-$ forms. Yet, nitrates leach more than ammonium because of ammonium adsorption to soil colloids (55). Savant (56) found that ammonium-N movement in soil was slower than nitrate movement. Boating and Ballard (7) also found that nitrate

leaching exceeded ammonium leaching in forest soils. However, according to Gupta et al. (22), much of the ammonium from urea-N is nitrified to nitrate and is subsequently lost, especially if heavy precipitation occurs.

Other disadvantages of urea application exist besides the major disadvantage of volatilization. Kirby and Mengel (43) discovered that urea-N application resulted in a disturbance of plant protein metabolism and asparagine accumulation was increased in the plants tested. Boateng and Ballard (7) discovered that the soil pH changed enough after urea application to cause micronutrient solubility and leaching. Copper and iron leached soon after urea application because of the mobilization of metal-organic complexes. Manganese and zinc leaching occurred later after increased acidity of the soil caused by nitrification prompted by urea application.

The method of urea application has an effect on reaction in the soil. Creamer and Fox (12) found that band application of urea caused greater toxicity problems to corn than a similar band application of diammonium phosphate and, consequently, inhibited germination and reduced yields. This toxicity was more pronounced as soil temperature decreased. The decrease in temperature inhibited nitrification, maintained a high pH, and prolonged the proportion of total $NH_4^+$ + $NH_3$-N concentration present as free $NH_3$. Free $NH_3$ is toxic to respiratory cells and nitrifying bacteria.

Page (49) compared the application of urea to aqueous injections and to broadcasting and their influence on root response

of cauliflower transplants. He found that broadcasting urea fertilizer causes immediate response of the rooting system and resulted in earlier harvests compared to harvests resulting from treatments of injected aqueous urea. He stated that access to injected aqueous urea required growth of the root system and resulted in a delayed growth response.

In three field experiments Nyborg and Malhi (47) reported that urea applied as large pellets (2.1 g) in the fall produced twice the increase in yield of spring-sown barley compared to conventional incorporation or banding.

Sulphur Coated Urea (SCU)

Sulphur coated urea (36-38%N) is a slow release fertilizer which is manufactured by the National Fertilizer Development Center, Tennessee Valley Authority. TVA started a pilot plant in 1968 to manufacture SCU and by 1976, had made their first commercial shipments of SCU to fertilizer distributors (54).

A typical SCU granule is about 20 percent coating. This 20 percent coating includes 17 percent sulphur, 3 percent wax, 0.2 percent coal tar and 1.8 percent conditioner (6,53). The manufacturing process of SCU involves the application of three coatings to pre-heated urea granules. First, a uniform molten sulphur is sprayed as the basic coating material. The sulphur coating, even tested at 40 percent coating, did not prove to be a sufficient moisture barrier or to prevent the rapid dissolution of nitrogen.

Since these sulphur shells possessed microscopic pores and cracks allowed moisture and microbe penetration, a hard wax (melting point 165°F; oil content 10 percent) is applied as a second coating over the sulphur coating to prevent moisture penetration. A microbicide (coal tar or pentachlorophenol) is incorporated into the wax to prevent microbial penetration. The granules are sticky and cohesive after the second coating application and they aggregate quite easily. Therefore, a third coating is applied which is a diatomaceous earth conditioner that absorbs excess sealant and gives SCU proper handling and storage characteristics (6,25,53,54,63).

The standard measure of SCU quality is a seven-day release test of N in quiescent water at 37.8°C (25). The dissolution rate under such a test should be between 17.5 and 35 percent and also possess a dissolution rate of 1 percent per day or less after the seven-day period (54).

There are several benefits of SCU as a slow release fertilizer (2,30,54,63). The major benefit of SCU slow release fertilizer is that it increases the efficiency of nutrient utilization. SCU accomplishes this by allowing a longer duration of nitrogen release and by reducing non-productive (luxury) consumption of nitrogen by the plant. Fertilizer efficiency is also increased by reducing nutrient losses due to leaching. Since the leaching of nitrogen is reduced, the acidification of the subsoil is minimized which would reduce the restriction of plant root growth (30). Because of the conservation of nitrogen, fewer applications are

necessary for adequate nitrogen fertilization. Nitrogen is conserved by SCU also by the decrease in ammonia volatilization because of the reduction of immediate urea exposure to environment (30).

Other benefits include the satisfaction of soil sulphur requirements provided for by the SCU coating and the improvement of the physical quality of the granules of nitrogen fertilizer. The improvement of the physical quality of granules enhances better handling and storage especially for bulk blending.

Sulphur coated urea has three basic disadvantages. First, efficiency of it is low for crops which require all of their nitrogen over a relatively short period of time (43). The relatively higher cost per unit of nitrogen is the second disadvantage of SCU (30,43, 54,63). SCU costs approximately 50 percent more per unit of nitrogen than uncoated urea (54). A third disadvantage involves the sulphur coating itself. The sulphur coating has been found by Waddington (64) to have an acidifying effect on the soil, yet this reaction is not considered as a significant problem.

Dissolution or release rates of N are not the same for all SCU products. The release rates of individual SCU granules may vary because of different soil temperature or moisture, variance in coating, or imperfectly coated or cracked particles. However, the variability among individual granules balance each other into a uniform release rate (64). Urea is released from SCU by the erosion of the coating. Erosion of the coating is caused by the occurrence of small openings in the coating shell. The dissolution of nitrogen is measured by its diffusion rate out of these openings.

Jarrell and Boeroma (32) cite three mechanisms by which the coating erodes. First, the wax sealant is absorbed by surrounding soil particles. Second, the conversion of polymeric, amorphous sulphur to the crystalline form which results in cracking of the sulphur shell. Third, digestion of the coating by soil micro-organisms.

Several factors in the manufacture of the SCU product influence its rate of nitrogen dissolution.

As the coating weight increases the substrate dissolution rate decreases. As the substrate particle size increases the dissolution rate decreases due to the increased surface:volume ratio. Sulphur spray conditions which affect the substrate dissolution rate include such factors as the atomizing air pressure, number of spray nozzles, distance to substrate bed, etc. (6,53).

Several active factors affect the substrate dissolution rate of SCU. As soil temperature, moisture content, and aeration increase, the SCU dissolution rate of SCU increases, particularly if certain actinomycetes and genera of bacteria are present. The rate of nitrogen release increases with a rise in soil pH because a low soil pH has an adverse effect on the activity of soil microbes. Soil nutrient status also has an effect on microbial activity. The reduction of calcium and phosphorous limit the rates of microbial activity and thus affects the rate of N release from SCU granules in the soil (31,32). Dissolution rates of SCU granules is decreased also by surface application of the fertilizer as opposed to incorporation (31).

Sulphur coated urea is very beneficial for vegetable production. Russell et al. (54) cited that a single application of SCU is sufficient for vegetable production in a single growing season. Weidenfield (65) tested slow release fertilizer (SCU) and soluble nitrogen fertilizers and their influence on cantaloupes and bell pepper yields. He found that SCU was superior in performance to soluble nitrogen fertilizers applied preplant. In this experiment, he found that a single application of SCU was equal in performance to that of split applications of urea. Shelton (59) reported that a single application of SCU produced greater tomato yields than yields from five to six split applications of ammonium nitrate.

Sulphur coated urea is as effective as or more effective than uncoated urea in vegetable production. Huffman et al. (30) and Russell et al. (54) cited that vegetable crops have yielded better from the application of SCU than from the application of other nitrogen fertilizers. This is especially true with extensive precipitation on sandy soils. Locascio and Fiskell (39) reported that bell pepper yield response from SCU applications was similar to that from three split urea applications. However, lower fertilizer rates of SCU may decrease its effectiveness. In an earlier experiment (38) with bell pepper production, they reported that with low rates of SCU fertilization, pepper yields were lower in comparison with yields resulting from single urea applications. Yet, in this experiment, fertilizers were applied under polyethylene film mulch. This gave urea an advantage because plastic mulching had a

beneficial effect on nutrient efficiency of soluble nitrogen fertilizers (18,41). Locascio and Fiskell (40) also experimented with SCU performance on watermelon and bell pepper production in areas with high rainfall. They found that in these areas of high rainfall, SCU fertilization resulted in higher yields of peppers and watermelons than yields resulting from application of uncoated urea fertilizer.

CHAPTER III

# MATERIALS AND METHODS

Experiments were conducted at the University of Tennessee Plant and Soil Science Field Laboratory at Knoxville during the growing seasons of 1982 and 1983. The overall planting area was 18.6 x 35.0 meters on an Etowah fine loamy soil and consisted of 6 individual crops and/or cropping sequences arranged in a randomized complete block design with 4 replications. The cropping sequences included single crops of broccoli, squash, pepper and tomato and double crops of broccoli followed by squash or by pepper. Main plots of 7.6 x 1.7 meters were planted to each crop and consisted of double rows, 53.8 cm. apart on 107.5 cm. black plastic film. Plants were spaced 33.6 cm. for all crops except tomatoes which were spaced 40.3 cm. apart. Subplot treatments consisted of 2 sources of nitrogen fertilizer each at 2 levels. Subplots were superimposed on each main plot and data were pooled for the separation of the means of the projected gross returns for the crops and cropping sequences. The effects of two fertilizer sources (urea at 45%N and sulphur-coated urea at 36%N at 25% dissolution rate) and 2 levels (145 and 290 kg/ha) gave a randomized complete block design in a 2 x 2 factorial arrangement and were computed individually for each crop and/or cropping sequence. Fertilizer effects as well as cropping sequence effects were compared for broccoli, pepper, and squash alone or in a sequence of pepper or

squash following broccoli in a randomized complete block design in a 2 x 2 x 2 factorial arrangement.

The vegetable cultivars used were 'Premium Crop' (broccoli), 'Dixie Hybrid' (Summer yellow squash), 'Keystone Resistant Giant' (bell pepper), and 'Floradade' (tomato). Hybrid cultivars of broccoli, squash, and tomato were used because of the benefits of earliness of harvest, disease resistance, high yields, and product uniformity. 'Keystone Resistant Giant' is an open pollinated cultivar.

Data collected included yields by grade for each crop and a projected gross return for each crop. Quality of broccoli heads harvested was rated according to color, uniformity, and disease on a scale of 1 to 5 (1=unmarketable and 5=excellent quality). Other crops were graded by USDA standards.

During both years, essential cultural practices were performed including pesticide application, weed control, irrigation, and fertilization.

### 1982 Season

During the 1982 season, initial ground preparation included several steps. On April 7, superphosphate and muriate of potash (KCl) fertilizers were applied at the rates of 138 kg/ha and 190 kg/ha, respectively, and were disced and tilled into the soil to a depth of 8 cm. On April 12, the nitrogen fertilizer treatments were applied to each plot and plastic mulch was applied the same day with a

tractor drawn applicator. Holes were punched into the plastic at appropriate times and places for transplants and seeds.

All the vegetable crops used were seeded in the greenhouse except squash. Broccoli, a cool season crop, was seeded earliest on March 1. Peppers were seeded on March 5 and tomatoes were seeded on March 12. Yellow summer squash was seeded directly in the field on May 10.

Vegetable transplants were taken from the greenhouse to the field within 4-6 weeks. Spring broccoli was transplanted into the field on April 13-14. Peppers were transplanted April 20 and tomatoes were transplanted April 19. On April 29, 12 broccoli plants were replaced due to rodent damage.

Double crops were seeded later in the season. Peppers for the double crop were seeded on May 18 and were transplanted into the field on June 29. Squash for the double crop was seeded directly into the field on June 30.

Each vegetable crop was sprayed with the appropriate insecticides and fungicides to reduce stress on the plants caused by insect or pathogenic pests. Insecticides applied included Carbaryl (Sevin WP) and Malathion WP. Fungicides used included Maneb (Manzate WP) and Benlate SP. Maneb was used for leaf spot fungi and Benlate was used primarily for powdery mildew control on squash.

Weeds were controlled manually. No herbicides were applied. Tilling and hoeing were done on May 11, 13, 14, June 4, 7, and August 13, 16, and 26.

Four plants from each sub plot were selected for harvest and appropriate data were recorded. Broccoli heads were rated according to quality and symmetry. All squash, peppers, and tomatoes were counted, weighed, and graded according to USDA standards. Single crops of broccoli, squash, peppers, and tomatoes were harvested during the following dates:

broccoli--three harvests between June 2 and June 14

squash--ten harvests between June 16 and July 23

peppers--five harvests between July 1 and July 19

tomatoes--five harvests between June 30 and August 4

Harvests of the double crop of squash were completed at three different times between the dates of July 28 and August 9. The double crop of peppers following broccoli was harvested on August 17 and September 22.

After the last harvest of each crop, the plants were pulled out and the plastic was cleared of debris. Surrounding weeds were eliminated and the holes in the plastic were prepared for the following crop in the sequence.

## 1983 Season

During the 1983 season, initial soil preparation began on March 25. As in 1982, the same rates of phosphorous and potassium fertilizers of 138 and 190 kg/ha, respectively, were applied and disced and tilled into the soils. On April 4, nitrogen fertilizers were applied and incorporated. On the same day, the black plastic

mulch was applied and secured by a tractor drawn applicator. Holes were punched in the plastic mulching at the appropriate times and places for transplants and seeds.

Broccoli was seeded in the greenhouse on February 21 and transplants were planted into the field on April 13. Peppers and tomatoes were seeded on March 11. Tomatoes were transplanted into the field April 22, and peppers were transplanted May 6. The yellow summer squash was seeded directly into the field on May 10. Pepper for the double crop after broccoli was seeded in the greenhouse May 26 and was transplanted into the field on July 15. Squash after broccoli was seeded directly in the field on June 28.

The same insecticides and fungicides were used during the 1983 season as in the 1982 season. Insecticide and fungicide applications were performed on July 22, August 8, 22, 31, and September 16.

Weed control was accomplished manually and chemically. Hoeing was done on July 22, 26-29, August 12, 19, 23, and September 8. Herbicides that were applied were Bentazon (Basagran) and Glyphosphate (Round-up). Bentazon was applied June 9 for the control of yellow nutsedge. Glyphosphate was applied on August 31 for the control of all existing weeds. Both herbicides were directed between the plastic mulch rows.

Harvests were completed and yields were recorded as the previous year. The single crops of broccoli, squash, peppers, and tomatoes were harvested during the following dates:

broccoli--four harvests between May 25 and June 7

squash--ten harvests between June 11 and August 17

peppers--six harvests between July 5 and August 26

tomatoes--six harvests between July 11 and August 18

Squash following broccoli was harvested 12 times between August 9 and September 6. Peppers following broccoli were harvested three different times between the dates of September 6 and September 26.

In order to compare the economics of crops and cropping sequences, wholesale prices were obtained after each harvest. Monetary value was determined by multiplying yield in pounds by the wholesale price per pound of produce. Sources of wholesale prices were attained by cooperation of Neel's Produce and Turner Brothers Produce companies located on Forest Avenue, Knoxville, Tennessee.

Treatment effects were tested at the 5 percent level of significance and mean separations were performed by the Duncan's multiple range test using the Statistical Analysis System (SAS) programming (55).

# CHAPTER IV

## RESULTS AND DISCUSSION

The economic value and yield comparison of cropping sequences and differences among fertilization treatments varied considerably between the 1982 and 1983 growing seasons. These differences can be partially attributed to weather variations during both years. According to NOAA Climatological Data reports, the 1982 season had an excess in precipitation and the 1983 season had a deficit in precipitation (62). The excess in precipitation in 1982 resulted in increased incidence of disease, particularly with the double cropping sequence in the latter part of the season. Even though the use of black plastic mulch reduces leaching (10,16), the excess precipitation during 1982 may have caused depletion of nutrients at the root zone and consequently resulted in measurable differences in the effects from fertilizer treatments. However, this was not the case during the 1983 growing season. The deficit in precipitation, combined with the nutrient conserving capacity of black plastic mulching (9,10,11), probably resulted in adequate nitrogen levels in the root zone therefore resulting in no significant difference in crop yield or value due to different fertilizer treatments.

Early season temperatures during these two test years also contributed toward alteration of broccoli yield and gross returns. Both years had abnormally low temperatures, particularly in April

(62). These low temperatures occurred at different crucial times during that month. In 1982, there were temperatures below freezing. However, they occurred before broccoli was transplanted in the field while in 1983, temperatures below freezing occurred after broccoli was transplanted in the field. On April 20, 1983, -4°C was recorded in Knoxville, TN. During the same month, 5 days consisted of temperatures that were below freezing (62). By observation, the young transplants were determined to have been damaged or stunted during these freezes. The heads of broccoli harvested that year were extremely reduced in size and weight and, therefore, subsequent value.

Projected Gross Returns from Crops and Cropping Sequences

Four different crops were compared within these sequences and, therefore, for logical comparison to be made a common denominator among these treatments was determined. The common denominator chosen was the projected gross returns of each crop and cropping sequence based on wholesale prices recorded after each harvest (Table 1). Thus, the comparisons made among crops and cropping sequences were based on monetary value and are projected on a per hectare basis.

During both years, tomatoes gave the highest total value of all crops or cropping sequences. This can be expected due to the superior production potential and economic value of tomatoes (17). Tomatoes were significantly higher in gross returns than were

Table 1. Wholesale prices paid for vegetables in the Knoxville market by weeks in 1982 and 1983.

| | | $/kg | | | | | |
|---|---|---|---|---|---|---|---|
| Year | Week of Harvest | Broccoli | Pepper[x] | Pepper[y] | Squash[x] | Squash[y] | Tomatoes |
| 1982 | 1 | .92 | 1.51 | 1.02 | .43 | .39 | .98 |
| | 2 | 1.45 | .82 | .78 | .22 | .39 | 1.22 |
| | 3 | 1.18 | .55 | - | .37 | .39 | .82 |
| | 4 | - | .55 | - | .24 | - | .33 |
| | 5 | - | - | - | .39 | - | .33 |
| | 6 | - | - | - | - | - | - |
| 1983 | 1 | 1.41 | .82 | .67 | .55 | .61 | .75 |
| | 2 | 1.51 | .82 | .82 | .59 | .61 | .75 |
| | 3 | 1.41 | .82 | .82 | .59 | .71 | .82 |
| | 4 | 1.51 | .82 | - | .61 | .61 | 1.08 |
| | 5 | - | .71 | - | .61 | .61 | .75 |
| | 6 | - | .61 | - | - | .61 | .65 |

[x]Single crop.

[y]Double crop.

pepper, squash, or broccoli as single or sequential crops (Table 2). Broccoli and the double crops of broccoli-pepper and broccoli-squash had the second highest value next to tomatoes in the 1982 season (Table 2). The double crop of broccoli-pepper was significantly higher in value than the single crop of pepper or squash. This is expected because of the additive effect of two high value crops (58). Shaw and Everett (12) found that double crops increased net productivity of a given unit area and enhanced greater economic return. Also in 1982 the value of the double crop of broccoli-squash was significantly higher than the single crop of pepper (Table 2). However, the double crop of broccoli-squash or the double crop of broccoli-pepper was not significantly higher in value than the single crop of broccoli (Table 2). Thus, the squash or pepper crop which followed broccoli gave no significant economic contribution. The failure of the double crop of squash to give significant results might be attributed to the onset of powdery mildew prompted by heavy precipitation in the 1982 growing season (62) which severely reduced productivity. The failure of the double crop of peppers to give significant results of beneficial gross returns might be attributed to the late setting of the transplants in the field. High summer-time temperatures may have been detrimental to the young pepper transplants due to the heat build-up of the plastic mulch surface (10).

Single crops of broccoli, pepper, and squash were not significantly different in gross returns during the 1982 season

Table 2. Projected gross returns from all crops and cropping sequences, 1982-1983.

| Crop | Projected Gross Returns ($/ha)[y] | |
|---|---|---|
| | 1982 | 1983 |
| Broccoli | 19217 bcd[z] | 4989 d |
| Pepper | 15210 d | 10819 c |
| Squash | 17285 cd | 21608 b |
| Tomato | 51297 a | 27965 a |
| Broccoli & Pepper | 22823 b | 9203 cd |
| Broccoli & Squash | 20624 bc | 12177 c |

[y]Values projected from local wholesale market prices at time of harvests. Data are pooled for both formulations and levels of nitrogen fertilizer.

[z]Means within columns followed by the same letter are not significantly different at 5% level, Duncan's multiple range test.

(Table 2). Double crops of broccoli-pepper and broccoli-squash also were not significantly different in value during the same year (Table 2).

The results of crop returns were different in many instances between the 1982-1983 growing seasons, yet, there were also similarities. Tomatoes again gave the highest returns both years and were significantly higher in value than the other single or double crops (Table 2). The other single crops were significantly different from each other in estimated returns during 1983. The single crop of squash was second in value to tomatoes and was significantly higher in value than the other single or double crops (Table 2). During the 1983 season, conditions were more favorable for squash production (i.e., drier conditions and thus, less incidence of disease). Peppers were the third highest in value among the single crops (Table 2). The single crop of peppers was not significantly different in value from either double crops.

Broccoli, during the 1983 season, gave the least in value compared to all single and double crops, except the double crop of broccoli-pepper. As compared to 1982, this reduction in value can be attributed to the stunting and head size reduction caused by the late freezes in the spring season. Judging from previous claims of Clarkson (10) and Harris (24), even though stunting and poor growth of the broccoli plants occurred, the heat build-up of the microclimate around the broccoli plant caused by black plastic mulching could have allowed the transplants to survive the late

freezes and could have prevented total crop destruction. The reduction in value can not be attributed to lower wholesale prices during 1983 (Table 1). During the spring of 1983 the late freezes affected the entire nation causing nation-wide broccoli shortages. The shortage of broccoli actually caused the wholesale price to increase over the price of the previous year.

The gross returns of the double crops were also different during the 1983 season. During this season, the double crop of broccoli-squash was significantly higher in returns than the single crop of broccoli. Therefore, due to the lack of extensive precipitation and disease the squash following broccoli contributed significantly to economic return. However, the double crop of broccoli-pepper was not significantly higher in value from the single crop of broccoli (Table 2). Therefore, in this case the double crop did not contribute towards increasing economic value. The harvests of the double crop of peppers were terminated early and thus, yield potential may have been reduced substantially. This fact suggests that a double crop of broccoli-pepper may have a greater potential than the results demonstrated in this test. Comparison of value of the double crops broccoli-pepper and broccoli-squash did not differ significantly during the 1983 season (Table 2).

<u>Projected Gross Returns from Fertilizer Treatments</u>

Data from all crops were pooled to determine the effect of fertilizer on economic return of all crops. No significant effects

on gross returns were found among fertilizer treatments for either year (Table 3). The high rate of urea was the most effective in 1982, but was the least effective in 1983. Conversely, the low rate of SCU was the least effective in 1982, but was the most effective in 1983. According to previous research, it has been determined that black plastic mulch does not require the necessity of increased fertilizer rates for increased production. It also masks the effect of a slow release fertilizer. For example, Coizinsky and Overman (13) discovered that different fertilizer rates under plastic mulch had no significant effect on broccoli yields. Also, Locascio and Fiskell (41) found that plastic allows soluble fertilizer performance (i.e., urea) to perform similarly to a slow release fertilizer (i.e., SCU) and thus cancels the significant effect of fertilizer formulation variance.

Effects of Fertilizer Treatment on Crop Yield and Projected Gross Returns

The various treatments of nitrogenous fertilizer had a significant effect on some individual single and double crops. During the 1982 season, broccoli responded with differences to the various treatments. There was a significantly higher yield and value of broccoli resulting from the higher rate of urea (Tables 4 and 5). This result disagrees with the results cited in the test by Coizinsky and Overman (13) who stated that fertilizer rates had no significant effect upon broccoli production. There were no

Table 3. Influence of N sources and rates on projected gross returns from all crops and cropping sequences, 1982-1983.

| Formulation | Rate (kg N/ha) | Projected Gross Returns ($/ha) 1982 | 1983 |
|---|---|---|---|
| Urea | 145 | 25668[z] | 13570 |
| Urea | 290 | 26903 | 12888 |
| SCU | 145 | 23653 | 14776 |
| SCU | 290 | 25471 | 14188 |

[z]None of the means in columns differed significantly at 5% level, ANOVA.

Table 4. Influence of N source and rate on marketable yield and projected gross returns from broccoli, 1982 and 1983.[y]

| Treatment | | Marketable Yield (MT/ha) | | Projected Gross Returns ($/ha) | |
|---|---|---|---|---|---|
| Source | Rate (kg N/ha) | 1982 | 1983 | 1982 | 1983 |
| Urea | 145 | 14.32 b[z] | 3.43 a | 19004 b | 5073 a |
| Urea | 290 | 17.52 a | 3.63 a | 23144 a | 5385 a |
| SCU | 145 | 13.11 b | 3.39 a | 16890 b | 4994 a |
| SCU | 290 | 14.76 b | 3.63 a | 19044 b | 5365 a |

[y]Data are from all cropping sequences containing broccoli and are analyzed in a randomized complete block design by the General Linear Model procedure.

[z]Means within columns followed by the same letter are not significantly different at 5% level, Duncan's multiple range test.

Table 5. Influence of N source and rate on head diameter, quality rating, marketable yield and projected gross returns from broccoli, 1982 and 1983.

| Treatment | Head Diameter[w] cm. | | Quality Rating[x] | | Marketable Yield[y] (MT/ha) | | Projected Gross Returns ($/ha) | |
|---|---|---|---|---|---|---|---|---|
| | 1982 | 6.6 a | 1982 | 1983 | 1982 | 1983 | 1982 | 1983 |
| Source | | | | | | | | |
| Urea | 11.2 a[z] | 6.6 a | 1.6 a | 3.0 a | 15.92 a | 3.53 a | 21074 a | 5231 a |
| SCU | 10.9 a | 7.4 a | 1.5 a | 3.2 a | 13.94 b | 3.48 a | 17986 a | 5182 a |
| Rate (kg N/ha) | | | | | | | | |
| 145 | 11.2 a | 7.1 a | 1.5 a | 3.2 a | 13.75 b | 3.39 a | 17947 a | 5034 a |
| 290 | 10.9 a | 6.9 a | 1.6 a | 3.0 a | 16.12 a | 3.63 a | 21173 a | 6259 a |

[w]Measured across top of broccoli head.

[x]Ratings 1-5 (1 = unmarketable, 5 = excellent quality).

[y]Marketable yield = rating of > 1.

[z]Means followed by the same letter are not significantly different at 5% level, Duncan's multiple range test.

significant differences in diameter of broccoli heads or quality rating of broccoli due to fertilizer treatments (Table 5). In 1983 the broccoli head size was smaller probably due to the late freezes, however quality ratings were higher in 1983 than in 1982. Many of the broccoli heads were diseased in 1982. This may have been due to the excess precipitation during that year (62).

The other single crops of pepper, squash, and tomato demonstrated no significant differences due to fertilizer influence during either year of 1982 or 1983. The data for these crops appear in Tables 6-11, respectively.

There were significant differences in the yield of the double crop of squash following broccoli in 1982. There were no differences in yield by grade due to various N sources and rates of nitrogen fertilizers (Table 12). However, the double crop of squash gave higher yields from the use of the higher rate of SCU than from fertilizer treatments of a high rate of urea or from a low rate of SCU. However, the total yield resulting from the high rate of SCU was not significantly higher than the total yield of squash resulting from the low rate of urea (Table 13). The same results have been indirectly discovered in various other experiments. At times, high rates of soluble nitrogen fertilizers have been actually determined to be detrimental to vegetable production (17,18). Everett (19) also discovered that increased fertilizer rates under black plastic enhance double crop production. Locascio and Fiskell (38) also found that low rates of SCU application

Table 6. Influence of N source, rate, and source x rate interaction on marketable yield and projected gross returns from pepper, single crop, 1982 and 1983.

| Treatment | Marketable Yield[y] (MT/ha) 1982 | Marketable Yield[y] (MT/ha) 1983 | Projected Gross Value ($/ha) 1983 | Projected Gross Value ($/ha) 1983 |
|---|---|---|---|---|
| Source | | | | |
| Urea | 21.10[z] | 15.73 | 14138 | 10631 |
| SCU | 23.18 | 16.21 | 16302 | 11011 |
| Rate (kg N/ha) | | | | |
| 145 | 21.15 | 15.78 | 14553 | 10389 |
| 290 | 24.25 | 19.55 | 15882 | 11821 |
| Source x Rate Interaction | | | | |
| Urea-145 | 20.72 | 14.91 | 14272 | 12004 |
| Urea 290 | 21.44 | 11.66 | 13975 | 9248 |
| SCU-145 | 19.60 | 13.12 | 14835 | 10394 |
| SCU-290 | 24.64 | 14.52 | 17764 | 11629 |

[y]Marketable yield = total of No. 1 and No. 2 fruits.

[z]None of the means within treatments, in columns differed significantly at 5% level, ANOVA.

Table 7. Influence of N source and rate on fruit number and average fruit weight of pepper, single crop, 1982 and 1983.

| Treatment | Fruit Number (ha) | | | | | | Avg. Fruit Wt.[x] (kg)[y] | |
|---|---|---|---|---|---|---|---|---|
| | U.S. Fancy | | No. 1 | | No. 2 | | | |
| | 1982 | 1983 | 1982 | 1983 | 1982 | 1983 | 1982 | 1983 |
| Source | | | | | | | | |
| Urea | 7825 b[y] | 15649 | 53208 | 22694 | 130677 | 116593 | .11 | .09 |
| SCU | 15650 a | 15649 | 55555 | 14864 | 125199 | 144761 | .11 | .09 |
| Rate (kg N/ha) | | | | | | | | |
| 145 | 8606 a | 15649 | 50828 | 10956 | 129892 | 142415 | .10 | .10 |
| 290 | 14869 a | 24462 | 57906 | 25040 | 125979 | 129111 | .12 | .09 |

[x]Fruit weight = average weight of marketable fruit.

[y]Means in a column, within treatments followed by the same letter or no letter are not significantly different at 5% level, Duncan's multiple range test.

Table 8. Influence of N source, rate, and source x rate interaction on marketable yield and projected gross returns from tomatoes, 1982 and 1983.

| Treatment | Marketable Yield (MT/ha)[y] 1982 | Marketable Yield (MT/ha)[y] 1983 | Projected Gross Returns ($/acre) 1982 | Projected Gross Returns ($/acre) 1983 |
|---|---|---|---|---|
| Source | | | | |
| Urea | 79.13[z] | 32.23 | 52201 | 25702 |
| SCU | 79.71 | 36.25 | 50383 | 30228 |
| Rate (kg N/ha) | | | | |
| 145 | 80.10 | 36.40 | 52764 | 30410 |
| 290 | 78.75 | 32.14 | 49819 | 25515 |
| Source x Rate Interaction | | | | |
| Urea-145 | 80.73 | 34.85 | 55881 | 27881 |
| Urea-290 | 70.03 | 29.42 | 48427 | 23529 |
| SCU-145 | 73.08 | 37.61 | 49568 | 32950 |
| SCU-290 | 80.88 | 34.85 | 51213 | 27506 |

[y]Marketable yield = weight of No. 1 and No. 2 fruit.

[z]None of the means in columns differed significantly at 5% level, ANOVA.

Table 9. Influence of N source and rate on fruit number and average fruit weight of tomatoes, 1982 and 1983.

| Treatment | Fruit Number (ha) | | | | Avg. Fruit Wt. (kg)[y] | |
|---|---|---|---|---|---|---|
| | No. 1 | | No. 2 | | | |
| | 1982 | 1983 | 1982 | 1983 | 1982 | 1983 |
| Source | | | | | | |
| Urea | 272683[z] | 62599 | 206191 | 124794 | .17 | .18 |
| SCU | 289918 | 76298 | 191504 | 117769 | .17 | .20 |
| Rate (kg N/ha) | | | | | | |
| 145 | 284825 | 78625 | 205015 | 125979 | .16 | .19 |
| 290 | 277756 | 60219 | 193673 | 116593 | .17 | .19 |

[y]Average weight of No. 1 and No. 2 fruit.

[z]None of the means in columns are significantly different at 5% level, ANOVA.

Table 10. Influence of N source, rate, and source x rate interaction on marketable yield and projected gross returns from squash, single crop, 1982 and 1983.

| Treatment | Marketable Yield (MT/ha)[y] | | Projected Gross Returns ($/ha) | |
|---|---|---|---|---|
| | 1982 | 1983 | 1982 | 1983 |
| Source | | | | |
| Urea | 49.32[z] | 32.65 | 16395 | 21227 |
| SCU | 54.16 | 34.53 | 18174 | 21987 |
| Rate (kg N/ha) | | | | |
| 145 | 51.45 | 31.83 | 17482 | 20515 |
| 290 | 51.98 | 35.64 | 17092 | 22694 |
| Source x Rate Interaction | | | | |
| Urea-145 | 44.48 | 31.97 | 15086 | 20861 |
| Urea-290 | 54.09 | 33.42 | 17715 | 21582 |
| SCU-145 | 59.98 | 31.73 | 19873 | 20175 |
| SCU-290 | 49.74 | 37.38 | 16465 | 23820 |

[y]Marketable yield = total weight of No. 1 and No. 2 fruit.

[z]None of the means in columns are significantly different at 5% level, ANOVA.

Table 11. Influence of N source and rate on fruit number of squash, single crop, 1982-1983.

| Treatment | Fruit Number (ha) | | | |
|---|---|---|---|---|
| | No. 1 | | No. 2 | |
| | 1982 | 1983 | 1982 | 1983 |
| Source | | | | |
| Urea | 201892[z] | 119721 | 28953 | 66512 |
| SCU | 219098 | 115027 | 22694 | 77469 |
| Rate (kg N/ha) | | | | |
| 145 | 201102 | 129892 | 28948 | 60253 |
| 290 | 219879 | 104856 | 22694 | 83728 |

[z]None of the means in columns are significantly different at 5% level, ANOVA.

Table 12. Influence of N source and rate on fruit number of squash following broccoli, 1982 and 1983.

| | Fruit Number (ha) | | | |
|---|---|---|---|---|
| | No. 1 | | No. 2 | |
| Treatment | 1982 | 1983 | 1982 | 1983 |
| Source | | | | |
| Urea | 23474[z] | 79815 | 1565 | 18781 |
| SCU | 28563 | 95465 | 1565 | 9390 |
| Rate (kg N/ha) | | | | |
| 120 | 19562 | 85294 | 1170 | 8605 |
| 240 | 32475 | 89987 | 1956 | 19562 |

[z]None of the means in columns are significantly different at 5% levels, ANOVA.

Table 13. Influence of N source, rate, and source x rate interaction on marketable yield and projected gross returns from squash following broccoli, 1982 and 1983.

| Treatment | Total Marketable Yield (MT/ha)[x] | | Projected Gross Returns ($/ha) | |
|---|---|---|---|---|
| | 1983 | 1983 | 1982 | 1983 |
| Source | | | | |
| Urea | 2.81 a[y] | 10.30 | 1146 | 6792 |
| SCU | 3.39 a | 11.95 | 1368 | 7820 |
| Rate (kg N/ha) | | | | |
| 145 | 2.51 a | 10.79 | 1027 | 7039 |
| 290 | 3.63 a | 11.47 | 1482 | 7330 |
| Source x Rate Interaction | | | | |
| Urea-145 | 3.29 ab | 11.47 | 1047 | 6417 |
| Urea-290 | 2.27 b | 10.79 | 938 | 7167 |
| SCU-145 | 1.74 b | 11.76 | 785 | 7666 |
| Scu-290 | 4.98 a | 12.19 | 1279 | 7963 |

[x]Marketable weight = total weight of No. 1 and No. 2 fruit.

[y]Means in columns, within treatments, followed by the same letter or no letter are not significantly different at 5% level, Duncan's multiple range test.

resulted in lower performance than did that of a similar rate of urea application. In the experiment of Locascio and Fiskell the high rate of urea did not perform well and may have had detrimental effects due to its high rate as cited by Everett (17,18). The low rate of sulphur coated urea applied combined with the slow dissolution rate may have provided insufficient N for optimum plant growth (31, 63). In this research, the high rate of SCU gave the best results. The advantage of SCU is evident in that it is a slow release N-fertilizer which conserves nitrogen for a second crop (2,30). Due to the nutrient conserving capability of the plastic mulching (9,10,11) the low rate of urea performed well and yield from this treatment was not significantly different from that of the high rate of SCU application.

There were no significant differences of total weight or gross returns of the double crop of peppers following broccoli due to fertilizer influence during 1982 or 1983 (Table 14).

The number of U.S. Fancy grade peppers of the double crop was significantly higher due to the use of SCU in 1982 (Table 15). This is due to the SCU advantage of allowing a longer duration of nitrogen release for efficient uptake and use by the plant (2,30). The number of U.S. Fancy grade peppers of the double crop in 1983 were not significantly different (Table 15). No references were found that verify the effect of the interaction of fertilizer rate and N-source under plastic mulch affecting the relative production of a certain grade of a vegetable crop.

Table 14. Influence of N source, rate, and source x rate interaction on marketable yield and projected gross returns from pepper following broccoli, 1982 and 1983.

| Treatment | Marketable Yield (MT/ha)[y] 1982 | Marketable Yield (MT/ha)[y] 1983 | Projected Gross Returns ($/ha) 1982 | Projected Gross Returns ($/ha) 1983 |
|---|---|---|---|---|
| Source | | | | |
| Urea | 4.79[z] | 4.21 | 3961 | 3023 |
| SCU | 6.19 | 5.17 | 5147 | 3744 |
| Rate (kg N/ha) | | | | |
| 145 | 6.19 | 4.98 | 5162 | 3433 |
| 290 | 4.74 | 4.59 | 3947 | 3339 |
| Source x Rate Interaction | | | | |
| Urea-145 | 3.29 | 3.43 | 1170 | 2460 |
| Urea-290 | 2.27 | 4.64 | 1022 | 3378 |
| SCU-145 | 1.74 | 5.75 | 1309 | 4194 |
| SCU-290 | 4.98 | 4.54 | 1057 | 3319 |

[y]Marketable yield = weight of U.S. Fancy, No. 1 and No. 2 fruit.

[z]Means in a column are not significantly different at 5% level, ANOVA.

Table 15. Influence of N source and rate on marketable number and average fruit weight of pepper following broccoli, 1982 and 1983.

| Treatment | Fruit Number (ha) U.S. Fancy 1982 | U.S. Fancy 1983 | No. 1 1982 | No. 1 1983 | No. 2 1982 | No. 2 1983 | Avg. Fruit Wt. (kg)[x] 1982 | Avg. Fruit Wt. (kg)[x] 1983 |
|---|---|---|---|---|---|---|---|---|
| **Source** | | | | | | | | |
| Urea | 0000 b[y] | 780 | 10956 | 8605 | 32080 | 6120 | 0.13 | 0.09 |
| SCU | 4693 a | 000 | 13303 | 13303 | 36778 | 7197 | 0.10 | 0.09 |
| **Rate (kg N/ha)** | | | | | | | | |
| 145 | 3131 a | 000 | 13303 | 13268 | 39124 | 6407 | 0.11 | 0.10 |
| 290 | 390 a | 780 | 10171 | 8605 | 29709 | 6911 | 0.13 | 0.09 |

[x]Average weight of U.S. Fancy, No. 1 and No. 2 fruit.

[y]Means in column within treatments, followed by the same letter or no letter are not significantly different at 5% level, Duncan's multiple range test.

There were no significant differences in yield or returns during the 1983 season from the use of different treatments of source or rate of urea fertilizers. It is assumed that the lack of precipitation (62) during the 1983 growing season did not extensively leach or deplete any level of available nitrogen that was applied from any of the treatments.

The yield and value of the single crops of squash and pepper were compared to the yield and value of the double crop of squash and pepper. Both yield and value of both single crops were significantly higher than both double crops during 1982 and 1983 (Tables 16-20). This agrees with the experiments of Dalton (8) and Everett (19) who state that yields from double crop were 50-60 percent lower. However, they also emphasized that energy efficiency was greatly increased and that input costs for a second crop were 70-75 percent lower than for the initial crop. The differences in yield and value in this experiment are due mostly to factors relating to the cropping sequence (i.e., climatic differences, biological differences, nutrient depletion, etc.) according to the statistical analysis.

There were no significant differences, in 1982, in yield or value between single and double crops of pepper due to a difference in fertilizer rate (Tables 16 and 17).

All components of yield and value of the single and double crops of pepper in the 1982 season were not significantly different due to the different fertilizer source except for the yield of U.S. Fancy grade peppers. In this case the double crop of

Table 16. Influence of cropping sequence, N source and rate on marketable yield and projected gross returns from pepper, 1982 and 1983.

| Treatment | Crop | Marketable Yield (MT/ha)[x] | | Projected Gross Returns ($/ha) | |
|---|---|---|---|---|---|
| | | 1982 | 1983 | 1982 | 1983 |
| Cropping Sequence | single | 21.58 a[z] | 13.60 a | 15210 a | 10813 a |
| | double[y] | 5.47 b | 4.69 b | 4505 b | 3378 b |
| Source | single | 12.92 a | 0.24 a | 9015 a | 6822 a |
| | double[y] | 14.13 a | 0.14 a | 10704 a | 6880 a |
| Rate | single | 13.21 a | 0.19 a | 9825 a | 7380 a |
| | double[y] | 13.89 a | 0.14 a | 9889 a | 6886 a |

[x]Marketable yield = total weight of U.S. Fancy, No. 1 and No. 2 fruit.

[y]Following broccoli.

[z]Means in columns, within treatments, followed by the same letter are not significantly different at 5% level, Duncan's multiple range test.

Table 17. Influence of cropping sequence, N source and rate on fruit number, average fruit weight and marketable yield of pepper following broccoli, 1982.

| Treatment | Crop | Fruit Number (ha) | | | Marketable Yield (MT/ha) | | | Avg. Fruit Wt. |
|---|---|---|---|---|---|---|---|---|
| | | U.S. Fancy | No. 1 | No. 2 | U.S. Fancy | No. 1 | No. 2 | (kg)[x] |
| Cropping Sequence | | | | | | | | |
| | single | 11737 a[z] | 5473 a | 127936 a | 2.22 a | 7.26 a | 12.10 a | 0.11 a |
| | double[y] | 2346 b | 12122 b | 34431 b | 0.62 b | 1.84 b | 3.00 b | 0.12 a |
| Source | | | | | | | | |
| | single | 117374 b | 3912 a | 32080 a | 0.73 b | 4.16 a | 8.03 a | 0.12 a |
| | double[y] | 100889 a | 10171 a | 34431 a | 2.08 a | 4.98 a | 7.11 a | 0.11 a |
| Rate | | | | | | | | |
| | single | 122818 a | 5819 a | 32470 a | 1.26 a | 4.40 a | 7.55 a | 0.11 a |
| | double[y] | 120066 a | 8200 a | 34037 a | 1.79 a | 4.74 a | 7.55 a | 0.12 a |

[x]Average weight of U.S. Fancy and No. 1 and No. 2 fruit.

[y]Following broccoli.

[z]Means in columns, within treatments, followed by the same letter are not significantly different at 5% level, Duncan's multiple range test.

Table 18. Influence of cropping sequence, N source and rate on fruit number, average fruit weight and marketable yield of pepper following broccoli, 1983.

| Variable | Crop | Fruit Number (ha) | | | Marketable Yield (MT/ha) | | | Avg. Fruit Wt. (kg)[x] |
|---|---|---|---|---|---|---|---|---|
| | | U.S. Fancy | No. 1 | No. 2 | U.S. Fancy | No. 1 | No. 2 | |
| Cropping Sequence | | | | | | | | |
| | single | 1566 a[z] | 18781 a | 130677 a | 0.29 a | 2.47 a | 10.8 a | 0.09 |
| | double[y] | 390 b | 10956 b | 6659 b | 0.09 b | 1.35 b | 3.24 b | 0.08 |
| Source | | | | | | | | |
| | single | 1175 a | 15649 a | 61354 a | 0.24 a | 2.08 a | 6.43 a | 0.09 |
| | double[y] | 780 a | 14083 a | 75977 a | 0.14 a | 1.74 a | 6.67 a | 0.08 |
| Rate | | | | | | | | |
| | single | 1175 a | 17215 a | 66606 a | 0.01 a | 2.27 a | 6.92 a | 0.09 |
| | double[y] | 780 a | 12517 a | 70735 a | 0.14 a | 1.55 a | 7.11 a | 0.08 |

[x]Average weight of U.S. Fancy and No. 1 and No. 2 fruit.

[y]Following broccoli.

[z]Means in columns within treatments followed by the same letter are not significantly different at 5% level, Duncan's multiple range test.

Table 19. Influence of cropping sequence, N source and rate on number, weight, and projected gross returns from squash, 1982.

| Treatment | Crop | Fruit Number (ha) | | | Marketable Yield (MT/ha) | | | Projected Gross Returns ($/ha) |
|---|---|---|---|---|---|---|---|---|
| | | No. 1 | No. 2 | Total Number | No. 1 | No. 2 | Total Weight | |
| Cropping Sequence | | | | | | | | |
| | single | 210458 a[z] | 25821 b | 236314 a | 42.11 a | 9.58 a | 51.74 a | 17275 a |
| | double[y] | 25979 b | 1565 b | 27604 b | 2.81 b | 0.24 b | 3.04 b | 1249 b |
| Source | | | | | | | | |
| | single | 82942 a | 10704 a | 93588 a | 14.76 a | 4.07 a | 18.29 a | 6194 a |
| | double | 92086 a | 8605 a | 105167 a | 17.08 a | 3.19 a | 20.28 a | 7009 a |
| Rate | | | | | | | | |
| | single | 80062 a | 10388 a | 90505 a | 14.57 a | 4.21 a | 18.82 a | 6510 a |
| | double | 94902 a | 8827 a | 103789 a | 17.18 a | 2.51 a | 19.74 a | 6634 a |

[y]Following broccoli.

[z]Means in columns, within treatments, followed by the same letter are not significantly different at 5% level, Duncan's multiple range test.

Table 20. Influence of cropping sequence, N source and rate on number, weight and projected gross returns from squash, 1983.

| Treatment | Crop | Fruit Number (ha) | | | Marketable Yield (MT/ha) | | | Projected Gross Returns ($/ha) |
|---|---|---|---|---|---|---|---|---|
| | | No. 1 | No. 2 | Total Number | No. 1 | No. 2 | Total Weight | |
| Cropping Sequence | | | | | | | | |
| | single | 117374 a[z] | 71990 a | 189365 a | 18.39 a | 15.24 a | 33.69 a | 21597 a |
| | double[y] | 87640 b | 14083 b | 101724 b | 9.34 b | 1.79 b | 11.18 b | 7262 b |
| Source | | | | | | | | |
| | single | 99783 a | 42632 a | 142415 a | 13.69 a | 7.84 a | 21.54 a | 13960 a |
| | double[y] | 105241 a | 43383 a | 148674 a | 14.03 a | 9.20 a | 23.33 a | 14899 a |
| Rate | | | | | | | | |
| | single | 107588 a | 34431 b | 142025 a | 18.87 a | 6.43 b | 21.34 a | 13772 a |
| | double[y] | 97416 a | 51642 a | 149069 a | 12.83 a | 10.55 a | 23.47 a | 15086 a |

[y]Following broccoli.

[z]Means in a column, within treatments, followed by the same letter are not significantly different at the 5% level, Duncan's multiple range test.

peppers receiving the SCU produced a significantly higher number and weight of U.S. Fancy grade fruits than that produced from the single crop of peppers (Table 17). Locascio and Fiskell also found that bell pepper production responds best to a high rate of SCU fertilization (38).

During the 1983 season, however, there were no significant differences in yield or value between single and double crops of pepper from fertilizer source or rate (Tables 16 and 18).

Fertilization formulation caused no significant differences in yield or value between single and double crops of squash. However, in 1982, the single crops of squash were significantly higher in yield of number two grade squash than the yield of number two grade squash of the single crop due to fertilizer rate (Tables 19 and 20). Even though these results displayed significant differences, the application of this information would not be important. Number two grade squash was included as marketable in this experiment, however, the quality of this grade is not consistently desirable with the market.

Fruit size of peppers or tomatoes was not affected by fertilizer during 1982 or 1983 (Tables 7, 9, 15, 17, and 18, pages 42, 44, 51, 54, and 55, respectively).

Even though the statistical analyses demonstrated that the fertilizer influence on projected gross returns were not significantly different in most cases, an individual producer might find the magnitude of difference due to fertilizer profitable in the management system in this experiment.

# CHAPTER V

## SUMMARY AND CONCLUSIONS

Projected gross returns of the selected crops and cropping sequences studied demonstrated significant differences each year; however, differences due to fertilizer treatments were not as pronounced. The responses between the years of the study may be attributed largely to varying weather conditions.

There were significant differences among gross returns from the various crops and cropping sequences each year, but most differences were incongruent from one year to the next. Due to the inconsistencies between 1982 and 1983, it could not be definitely concluded if a double crop gives significantly higher returns than a single crop.

There were some similarities, however, between years. First, the results during both years of this study indicated that the production of tomatoes was superior in dollar returns to those from broccoli, pepper, squash, or combination of these in double crop sequences. Second, during 1982 and 1983 the estimated returns of both double crops of broccoli-pepper and broccoli-squash were not significantly different from each other.

Generally, the effect of different rates and sources of nitrogen fertilizers applied beneath black plastic mulch did not result in significant differences in yield or gross returns, particularly in the performance of single crops with the exception

of the single crop of broccoli during 1982. Here, the yield of broccoli was significantly higher from the use of urea fertilizer at the higher rate.

The second crops of a double crop sequence demonstrated more pronounced differences in yield due to the various fertilizer treatments than among single crops. The application of a higher rate of SCU increased yields of the double crops of pepper and squash.

Several conclusions can be made from these results. First, the production of tomatoes, regardless of N source or rate gave the greatest returns of all crops or cropping sequences studied. Second, since the yield of broccoli was increased from the use of the 290 $kg \cdot ha^{-1}$ rate as opposed to the 145 $kg \cdot ha^{-1}$ rate of urea, the effects of nitrogen fertilizer rates and sources on broccoli yield should be analyzed more extensively in the future to confirm or to negate these results. Third, the 290 $kg \cdot ha^{-1}$ rate of SCU appears to be a promising N source and rate for the production of double crops.

Two basic observations encourage the need for change of some of the design of this experiment. First, a nitrogen fertilization experiment such as this one should be extended over a longer period of time. Such an extension would help reduce climatic effects that might have affected the tests between 1982 and 1983. Second, for fertilization experiments, each crop or cropping sequence should be tested separately on larger plots in order to increase the sample size and, consequently, increase the accuracy of data

acquisition. Also, if more levels or sources of N were tested, there might be differences shown with crops which were not detected in this experiment.

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# VITA

Philip William Ramsey was born in Knoxville, Tennessee on April 14, 1959. He attended South High School and graduated June 1977. He attended The University of Tennessee, Knoxville, and received his B.S. in Plant and Soil Science in December 1981. He was employed as an undergraduate research assistant for The University of Tennessee, Knoxville, for a period of approximately three years. Upon graduation, he immediately entered Graduate School at The University of Tennessee, Knoxville, in January 1982. While completing a M.S. in Plant and Soil Science, he was employed as a graduate research assistant.

He is married to Shelley Rae Ramsey.