The Effects of Fertilizer on Burley Tobacco, *Nicotiana tabacum*

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Abstract

Burley tobacco is an important agriculture crop in the southern United States and is a major contributor to farm incomes where it is grown. The effectiveness of tobacco fertilization application is an important factor in overall quality and yield. Fertilizer is a major input cost in tobacco production. Macronutrients nitrogen, phosphorus, and potassium play key roles in tobacco yield and quality. Research shows, however, that reduced amounts of these nutrients can result in similar quality and yield, while reducing overall cost. Side banding versus the more common practice of broadcasting can help reduce the input cost and also help to improve the quality and yield of the crop. This research took place near Jonesborough, Tennessee during the 2013 growing season. Three different fertilizer methods, side banding, broadcasting, and broadcasting plus side banding, were applied to the research plots to observe effects on height and yield. The research proved that there was a significant difference in plant height and yield. The side banding method produced a taller stalk as well as higher yields when compared to the broadcasting method. However, more nitrogen was applied in the side banding method and this likely affected yields as well. Therefore, it was difficult to determine whether method of fertilizer application alone increased tobacco yields in this experiment. Even so, the side banding method did produce higher yields, equivalent quality, and was more cost effective than the other two methods in this study.

Table of Contents

List of Tables and Figures

Chapter I

Introduction

Burley tobacco (*Nicotiana tabacum)* is a member of the *Nicotiana* genus (Lewis and Nicholson, 2007). Tobacco is still an important source of farm income in the U.S. Producers in eleven states grow tobacco, totaling over 1.48 billion pounds per year (North Carolina Cooperative Extension Service, 2008). Tennessee is one of the five principal states with burley tobacco acreage and production along with North Carolina, Kentucky, South Carolina, and Virginia (Durand and Bird 1950). In the past decade, however, burley tobacco acreage and production has taken a downward turn due to the tobacco buyout and other factors.

Kentucky produces the majority of all tobacco nationwide, growing more that 70 percent of the total U.S. acreage (University of Tennessee CTGR). Tennessee is second, growing about 12 percent of the burley tobacco produced in the U.S. Indiana, North Carolina, Missouri, Ohio, Virginia, and West Virginia produce most of the remaining burley tobacco grown in America.

Production of burley tobacco for sale started in seventeenth-century Virginia and North Carolina (Bennett, 2012). Colonial inspection laws shaped the technology system and set specific practices. The American Revolution opened up the growing market to farmers, and as settlers moved west so did tobacco production (Bennett, 2012). Historically, tobacco was an American grown crop; now it is grown worldwide. The demand for domestic burley grown in the United States is declining not only due to the tobacco buyout, but also due to higher taxes, smoking restrictions, shifting of U.S. cigarette production overseas, and technological changes in cigarette manufacturing. The tobacco buyout program was established in 2004. It helped tobacco producers transition to the free market. Growers could get buyout money until 2014.

Burley tobacco production in North and South America has stayed relatively constant in the past few years, but production in Africa has more than doubled (North Carolina Cooperative Extension Service, 2008) . African tobacco does not have the same quality as tobacco grown in the U.S. and Brazil, but it does create “filler” that could impact economic returns domestically (North Carolina Cooperative Extension Service, 2008).

Chapter II

Literature Review

Economic impacts of burley tobacco in agriculture

Tobacco is an important crop in Appalachian communities. It plays a major role in the economies of many farms in the area. Tobacco is the seventh largest cash crop in the U.S. It is the most valuable crop on a per-acre basis and is significantly more profitable than other crops (USDA National Agricultural Statistics Service, 1998). Grain crops like wheat, soybeans, and corn average about $500 per acre or less in profit, whereas tobacco can average over $4,000 per acre (Wood, 1998). This accounts for a large share of the incomes of many tobacco producers in Tennessee.

Not only does tobacco have an important impact on local farms, but the tobacco industry plays a crucial role in the economy of the federal government. In 1998, tobacco consumers spent nearly $59.3 billion on tobacco products (Gale et al., 1999). Based on these numbers, tobacco production can be an important source of tax revenue. Beyond the farm, tobacco leaf makes billions of dollars for others including people who work with storing, marketing, advertising, and transporting tobacco and tobacco products (Gale et al., 1999).

Growing tobacco in the Southeast

The process of growing tobacco is an extensive process and it can be a 12 month a year crop. Seeds are started in float trays as early as March and managed in a greenhouse until transplanting, which usually occurs May thru June. The plant is topped to remove flowers at around 10-12 weeks and later is harvested for its leaves. The majority of tobacco grown in

America is cured by air curing, flue-curing, or fire-curing (University of Tennessee CTGR). The curing methods used help reduce the moisture content and impact the aroma of the future product: chewing tobacco, cigarettes, or others.

Essential elements needed for growth

Almost all plant life requires 17 essential elements to survive and grow to its optimal potential. However, nitrogen, phosphorus, and potassium are the major elements needed by the plants and the ones that cause the most concern when growing burley tobacco. Without adequate soil tests, producers can over or under fertilize the crop. Extra nitrogen can be lost through leaching through the soil and never benefits the plant. Potassium and phosphorus are not lost to leaching and can build up over time, causing an over-abundance of these elements. Potassium and phosphorus can potentially cause plant problems in certain stages of the growing season, if present in excess amounts (North Carolina Cooperative Extension Service, 2008).

Other macronutrients such as calcium, magnesium, and sulfur play crucial roles in tobacco growth. Essential micronutrients such as boron, zinc, iron, copper, and manganese are also essential to the plant, but are needed in smaller amounts. These nutrients combined help in adding strength and color to tobacco plants and help with metabolism of nutrients.

Burley tobacco can be very taxing on the soil. It is often recommended that tobacco crops be rotated every two years with a clover or grass mixture crop. Burley tobacco has a production period of 85-95 days in the field. A good crop of burley tobacco can remove more than 200 lbs of nitrogen, 35 lbs of phosphate, and 240 lbs of potash per acre while ideally producing 2.5 to 3 tons of dry leaf matter for sale (North Carolina Cooperative Extension Service, 2008).

Nitrogen in burley tobacco

Nitrogen is a very important nutrient that is used by all plants. It comes in many forms and is taken up by the plants in several ways. Nitrogen exists in multiple oxidation states and chemical forms. The most plentiful form of nitrogen is nitrogen gas (N_2), which makes up 78 % of the atmosphere, and must be fixed by microorganisms before it is useable by other organisms (Francis, 2007). Nitrogen exists in its most reduced state within organisms, but is rapidly nitrified to nitrate (NO_3^-) when released following cell death and lysis. Nitrate is then denitrified to nitrogen gas under suboxic and anoxic conditions, completing the nitrogen cycle (Francis 2009). Nitrogen also comes in other usable forms such as anhydrous ammonia (NH_3) and urea [$CO(NH_2)_2$], which are the most common in agriculture practices (Magasanik, 2009).

Nitrogen is the most studied element in tobacco fertilizer research. Different rates of nitrogen are recommended depending on which research one looks at and where it was conducted. However, most researchers recommend 150-250 pounds of N per acre for tobacco production. According to the North Carolina Cooperative Extension Service (2008), about 160 to 175 pounds of nitrogen per acre are recommended on fields producing less than 2,500 pounds of tobacco per acre and about 200 pounds per acre are recommended for crops producing more than 2,500 pounds per acre.

Excessive nitrogen fertilization increases the cost of production and can potentially increase pollution of ground and surface water due to leaching. Accumulation of nitrates in the leaf due to excessive nitrogen can negatively impact leaf quality of burley tobacco. Nitrogen use efficiency depends on soil processes, fertilization practices and physiology (Sifola and Postiglione, 2003). In burley tobacco, MacKown and Sutton (1997) found that fertilizer nitrogen use efficiency was 36.6% when nitrogen was broadcast. When side-dressed, nitrogen recovery increased to 43 to 54%, depending on the location.

Research from the University of Kentucky indicated that high nitrogen levels cause several problems, such as poor leaf quality (University of Kentucky Extension Lime and Nutrient Requirements 2014-2015 AGR-1). This can be found in the curing process, resulting in bright colored tobacco, and fat stems. Young, fast growing plants that have taken up excessive amounts of nitrogen are susceptible to disease. The biggest factor that most producers are concerned with is the waste of money. Loss of money results not only from the waste due to over application of fertilizer, but also from poor quality.

Phosphorus in burley tobacco

Phosphorus has been over used in tobacco production for many years. Phosphorus in most soils is adequate for burley tobacco production, but fertilization with phosphorus does increase the rate of early growth of tobacco (McCants and Woltz, 1967). Signs of phosphorus deficiency include the slow growth of the tobacco plant, especially in the early stages of growth. The leaves tend to be narrower and white spots might occur on the lower leaves of the plant. In some instances the plant does not mature properly, the leaves are low quality, and the cured leaves are dark brown because of immaturity (McCants and Woltz, 1967).

Most tobacco phosphate fertilizer comes in the forms of diammonium phosphate or DAP. Other forms are MAP (monoammonium phosphate), urea phosphate, and phosphoric acid. The rapid growth of burley tobacco is due to phosphorus and nitrogen uptake. Phosphorus also affects the growth of tobacco by decreasing the time required for the plants to reach maturity. Excessive amounts of phosphorus are generally not considered to have adverse effects on tobacco (McCants and Woltz, 1967). On the other hand, low amounts of phosphorus resulted in higher leaf yields than heavier applications (McCants and Woltz, 1967).

Potassium in burley tobacco

Potassium uptake occurs at a constant rate through the growing season, whereas nitrogen uptake does not. The amount of potassium absorbed is considerably lower than any of the other major elements. Potassium affects the quality of burley tobacco cured leaf. Many soils, however, do not have sufficient amounts of potassium to produce the needed quality without fertilization. The amount of potassium taken up varies among different application rates (McCants and Woltz, 1967). Overall though, the potassium requirements have not been sufficiently different to justify various rates of fertilizer applications (McCants and Woltz, 1967). A burley tobacco plant can also build a reserve of potassium early in its growth sufficient enough to carry it through the later stages of growth (McCants and Woltz, 1967).

Potassium fertilizer for burley tobacco is found in many forms: potassium nitrate (KNO_3), potassium sulphate (K_2SO_4), potassium bicarbonate ($KHCO_3$), and others. In some burley operations, potassium can be applied three times: in transplant water, 15 days post-transplant, and 30 days post-transplant.

Fertilizer Application

Side banding vs broadcasting application

Side banding tobacco was historically done by hand placing a “band” of fertilizer directly beside the plant. This fertilizer band is now applied while cultivating using a tractor equipped with a fertilizer hopper. By doing this, a producer can reduce fertilizer cost. Applying directly beside the plant reduces the over spread that broadcasting might have. The drawback to side banding tobacco is that is it more labor intensive.

Broadcasting, on the other hand, is usually done with a cyclone spreader or a fertilizer truck. The fertilizer is usually pre-mixed and brought to the field and spread at the location. The advantage is that the process takes less time and effort. On the other hand, some parts of the field might get more fertilizer than other parts. A disadvantage is that there is a certain amount of fertilizer spread on areas that are not planted.

Research has shown that one-half to two-thirds as much fertilizer is required to produce tobacco crop yields when it is properly banded compared to when it is broadcast (Sims and Wells 1985). The effectiveness of banding varies widely and is affected by soil nutrient levels, soil temperature, soil pH, and the mobility of the nutrient being applied. The best results occur when the soil has low levels of certain nutrients such as nitrogen, phosphorus, and potassium. Macronutrients such as calcium and magnesium can also be added directly to the plant by using the banding method. Broadcasting and side banding have almost the same yield effects on soils with medium to high soil testing levels and high pH (Sims and Wells, 1985.) Side banding can be more effective than broadcasting at lower rates per acre. This can significantly lower fertilizer cost.

Other advantages to side banding burley tobacco include less manganese toxicity, improved early growth, fewer days to maturity, and increased cured leaf yields (Sims and Wells, 1985). For best results, side bands of fertilizer are usually placed 12 inches from the row and 4 to 5 inches deep. This allows transplants to become established before roots permeate the fertilized soil. Broadcasting is more commonly used because it is easier and requires less labor on the front end. Broadcasting when not knowing soil nutrient levels cannot only be costly but can greatly increase the salt concentration of the soil and even decrease the soil pH if too much fertilizer is applied. This could cause damage to the plant root and adversely affect the growth and yield of the tobacco crop.

Soil types needed for plant growth

Soils vary not only across states but also across counties and even within the same fields. A well-planned fertilization program depends on a good soil test and interpreting the test results correctly.   It is important to take soil samples at several locations across the tobacco field. Soil tests not only provide the ratio and amounts of recommended fertilizer applications, but also micronutrient levels and pH levels together with recommended lime application rates needed to raise pH to appropriate levels if needed.

Sims and Wells (1985) found that the greatest differences in the yield of burley tobacco depended on whether lime was used or not.   Without the proper pH, the uptake of all nutrients will be limited. Lime must be applied at least six months prior to planting to be effective during that growing season. Some lime can be applied later if it is thoroughly mixed into the plow layer by turning about one-half of the lime under with the cover crop and disking one-half of the lime in the surface when smoothing the field before transplanting (Sims and Wells, 1985).

Economic impacts of fertilizer use

Burley tobacco cured leaf yield, price, and quality can be altered through appropriate fertilization programs (Evanylo et al., 1988).   Fertilizer recommendations need to include maximum yield, fertilizer cost, labor for application, and anticipated return.   Based upon the increasing prices of fertilizer and tobacco yields, a farmer can save an estimated 10 to 12 cents per pound of cured leaf tobacco through efficient fertilizer use (North Carolina Cooperative Extension Service, 2008). Fertilizer cost in burley tobacco production can make up more than 15-20% of input cost. Research on appropriate fertilization recommendations is essential not only to high yields, but also to profitability. Many farmers tend to over-fertilize, which can cause many problems early in the growth of burley tobacco. Good fertilizer management practices should ensure that plants will be healthy and fast growing, producing high yields and ensuring better nutrient uptake. Soil testing is an important tool when determining appropriate fertilizer rates and application methods.

Research Objectives

The main purpose of this research was to examine the effects of various fertilizer application methods on burley tobacco grown in east Tennessee.

Chapter III

Research Methods

This study was conducted during the 2013 tobacco growing season near Jonesborough, Tennessee. The soil type in the field chosen for the project was Dunmore silty clay loam. The study examined the effect of various fertilizer methods on burley tobacco grown in eastern Tennessee. Three methods were used in the study: broadcast, broadcast plus side band, and side banding. In the broadcast treatments 9-18-27 fertilizer was used at a rate of 1,121 kg/ha (1000 lbs/acre). This provided 101 kg of N/ha (Table 1). In the broadcast plus side-band method 9-18-27 fertilizer was used to broadcast at a rate of 673 kg/ha (600 lbs/acre). Ammonium nitrate, 34-0-0, was used to strictly side band within two weeks after transplanting at a rate of 224 kg/ha (200 lbs/acre) and again at four weeks at a rate of 224 kg/ha (200 lbs/acre). This provided 213 kg of N/ha. In the side-banding method alone, 9-18-27 and 34-0-0 were used together on two occasions at a rate of 224 kg/ha (200 lbs/ac 9-18-27 fertilizer 200lbs/ac ammonium nitrate) per occasion. The side banded fertilizer was applied while cultivating the crop. One pass was made within two weeks of planting, and the other was at 4 weeks after transplanting. The total rate applied for this method was 896.8 kg/ha (800 lbs/acre). The total amount of nitrogen applied was 192 kg/ha. A soil test was done to determine the fertilizer rates applied.

The tobacco variety used for all plots was KT 209 LC. It is a later maturing variety with high yield potential. It contains the highest resistance to black shank of any burley tobacco variety, and also highest resistance to wildfire, TMV (tobacco mosaic virus), and many other diseases. This is a very popular burley tobacco variety in East Tennessee.

Table 1. Summary of fertilizer and nutrient rates used in each treatment in the tobacco experiment.

	Fertilizer Treatment		
	Broadcast	Broadcast/side band	Side band
Amount of 9-18-27 applied (kg/ha)	1121	673	447
Amount of 34-0-0 applied (kg/ha)	0	447	447
Total amount of fertilizer applied (kg/ha)	1121	1120	894
Total amount of nitrogen applied (kg/ha)	101	213	192
Total amount of phosphate applied (kg/ha)	202	121	80
Total amount of potash applied (kg/ha)	303	182	121

The tobacco plots were set up in a randomized complete block design. Four blocks were established using the three fertilizer treatments mentioned above (Figure 1). The blocks were placed in one research field. Spaces or roads were placed between each block to allow a spray to be used on the tobacco; however each plot within the block was labeled with flags not spaces. Each plot was 12 rows wide and approximately 15.24 meters (50 feet) in length. The plant spacing was set on 51 cm (20 inches) with a 107 mm (42 inch) row spacing. Based on the length and spacing in each plot, there were approximately 360 stalks of tobacco per plot or 60 sticks per plot.

Tobacco seedlings for the research were grown in a greenhouse in Greenville, TN. The seedlings purchased for the study were started the first week of April, and transplanted June 4 2014.

Block 4	Broadcast	Broadcast + Side	Side-dress
Block 3	Broadcast + side	Side-dress	Broadcast
Block 2	Broadcast	Side-dress	Broadcast + Side
Block 1	Side-dress	Broadcast + side	Broadcast

Figure 1. Plot plan in randomized complete block design.

Broadcast fertilizer was applied by mechanical hand spreader before the tobacco was planted. The soil was treated with Prowl (BASF)(Naphthalene) before planting to help reduce weed growth. Height was measured at 10 weeks, right at the budding stage before the tobacco was to be topped. The average of 10 plants was taken per plot.

During the third week of August the plants were topped and sprayed using Prime Plus (Syngenta (Flumetralin: 2-chloro-N-[2,6-dinitro-4-(trifluoromethyl)phenyl]-N-ethyl-6-fluorobenzenemethanamine) and MH-30 (Chemtura) (Maleic hydrazide potassium salt) to stop sucker growth. The plots were harvested the second week of September. The stalks were placed on tobacco sticks with 6 stalks per stick. All tobacco in the study was air cured in tobacco barns.

When processing the tobacco to get a weight per stick, ten sticks were selected randomly per plot from the barn and the total leaf weight was determined (not per grade). That was divided by ten to get the weight per stick for each plot and then converted to yield in kg/ha.

The data were analyzed using SAS to calculate ANOVA. Ryan-Einot-Gabriel-Welsch (REGWQ) multiple range test was used for mean separation because it is powerful when comparing all pairs of means.

Chapter IV

Results

Height

It is important to note that greater heights of tobacco plants do not necessarily mean greater yields or quality. Bud topping is recommend at 10% bloom overall across the crop for the cultivar used for the study.

Using an α=0.05, there was a significant difference among means based on the P value of 0.0468 (Table 1). Based on REGWQ multiple range test, the side-dressing application and the broadcast plus side-dress applications were not significantly different. However, plants in the broadcast alone treatment were significantly shorter than plants in the other two treatments (Table 2).

Table 2. ANOVA for effect of fertilizer treatment on tobacco height.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Block	3	0.002	0.0007	0.38	0.7685
Treatment	2	0.019	0.0097	5.32	0.0468
Error	6	0.010	0.0018		
Total	11	0.032			

Table 3. Effect of fertilizer application method on height and yield of tobacco plants grown near Joneborough, TN in 2013.

Fertilizer Method	Mean Height (meters)	Mean Yield (kg/ha)
Side-band	1.58 a$^{\xi}$	2694 a$^{\xi}$
Broadcast + Side-band	1.56 a	2635 ab
Broadcast	1.48 b	2558 b

ξMeans followed by the same letter are not significantly different by REGWQ multiple range test (α=0.05).

Yield

Tobacco yield has been the subject of many researchers, and is constantly being studied to determine how improvements can be made. Fertilizer application rates and methods can have a tremendous effect on yield.

Using an α=0.05, there was a significant difference among means according to the ANOVA (P=0.0344; Table 3). Based on the REQWQ multiple range test, the means of the side-dressing method and broadcast plus side-dress method were not significantly different (Table 2). Also, the mean yields from the broadcast plus side-dress method and the broadcasting alone method were not significantly different. However, the side-dress alone treatment had significantly higher yields than the broadcast alone method. Unfortunately, it is not possible to determine if lower yields in the broadcast treatment resulted from the method of the fertilizer application or from the lower amount of nitrogen applied in the broadcast treatment.

Table 4. ANOVA table for effect of fertilizer treatment on tobacco yield.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Block	3	15553.80	5184.60	1.73	0.2604
Treatment	2	37361.69	18680.84	6.22	0.0344
Error	6	18013.10	3002.18		
Total	11	70928.58			

Quality

The value of all tobacco crops is found in the leaf. The price received by tobacco producers is based on the leaf quality and weight of each tobacco bundle. Tobacco cultivars have changed drastically over the years. Resistance to disease and pests has helped to improve burley tobacco quality and minimize loss in quality and yield. The cultivar chosen for the study was considered because of its resistance to black shank and blue mold, and yield potential. Based on visual observations, tobacco quality for all fertilizer treatments was of top quality.

Chapter V

Discussion and Conclusion

Burley tobacco is an important crop to Tennessee agriculture. Many factors affect the growth of tobacco including fertilization rates. Nitrogen, phosphorus, and potassium are essential to plant growth, and it is important to optimize fertilizer rates for these nutrients to maximize yields and quality while minimizing input costs. More importantly, how the fertilizer is applied could result in differences in the quality and yield of the cured leaf and can impact the economics of burley tobacco.

In this study, the fertilizer and ammonium nitrate amounts applied in the side-band method differed from the amounts applied in the broadcast and broadcast plus sideband methods. This was due to the fact that a third pass to add fertilizer was not possible because of the size of the tobacco plants. Adding the fertilizer earlier could have been possible when applying the other treatments, but adding too much fertilizer during dry weather could have made the tobacco in the side band plots to burn or fire up in the early growing stages.

This research showed that there were significant differences in the height and yield of burley tobacco due to fertilizer treatments. The best yields were obtained in the two treatments that included side-dressing the fertilizer. However, these two treatments also had more total nitrogen applied than the broadcast only method. Therefore, it is not possible to determine if application method or nitrogen amount contributed to the lower tobacco yield.

The weather could be a considerable factor in any crop research. This factor was not considered in the study, but all plots were in the same field and received the same weather conditions. However, further research could show if certain weather conditions would also affect fertilizer methods. Since the research took place during one growing season, research under consecutive growing seasons could identify any relationships between weather and fertilizer methods.

Economic cost of each method must also be considered. The broadcast alone method is usually done by a spreader buggy before the crop is planted. However, the side-dressing method takes more time, fuel, and labor cost. This must be considered when choosing which method is appropriate for every individual operation. Less fertilizer was used in the side-dressing method so it was less expensive than the other two methods but still produced good yields. In addition, side-dressed fertilizer was applied at the same time the crop was cultivated, so there was no additional cost for fuel and only minimal extra cost for labor

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