INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN 2278 – 0211 (Online)

Effect of Nitrogen, Topping and Leaf Priming on Yield and Quality of Flue Cured Tobacco (Nicotianatabacuml) in Zimbabwe: A Review

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Abstract:
Tobacco is one of Zimbabwe's most valuable crop. It accounts for about 26 % agricultural gross domestic product and 61 % of agricultural exports. It is therefore important to review the main attributes governing yield and quality of the crop. Good progress has been made regarding the development of best tobacco management practices with the aim of achieving maximum economic yields. Nitrogen is one of the major nutrients that affects and influence tobacco yield and quality because it is part of all proteins, chlorophyll and enzymes. Topping stimulates the production of secondary plant products that accumulate in the leaves. These products give the cured leaf improved quality and smoking characteristics. A good sucker control program is necessary to ensure high yields of acceptable quality. The removal of primings from the tobacco plants in the field can improve the yield and quality of the harvested tobacco leaves especially that of the first reaping. This paper has reviewed the importance of Nitrogen, topping and leaf priming in tobacco management. However, there is still need to establish the best nitrogen and priming levels, which might vary with place and variety.

Keywords: *Tobacco, nitrogen, priming, topping, yield and quality.*

1. Introduction

Agriculture plays a pivotal role in Zimbabwe's economy and isthe backbone of the country's economy (FAO, 1999; UN - Zimbabwe, 2010). About 70 percent of the population depends on agriculture for food, income, and employment (UN - Zimbabwe, 2010). Tobacco is one of the crops grown in Zimbabwe and supplies raw materials required by some industries in Zimbabwe. In 2009, tobacco contributed at least 56 percent of the total agricultural export earnings of the nation and thus contributing at least 10 percent of the Gross Domestic Product (ZTA, 2015).

Tobacco is an agricultural crop with an important economic role in the producing countries such as Zimbabwe and Brazil. Some of the world's finest flavor tobaccos come from Zimbabwe. This is mainly because of the country's favorable soil and climatic conditions besides great management practices as a result of continuous research in tobacco production. At one point, the country's tobacco exports accounted for 20% of the world's flue-cured tobacco (ZTA, 2013). The Zimbabwe Tobacco Association (2013) pointed out that revenue obtained from tobacco exports alone constituted up to 30 percent of the total revenue obtained from exports. The report further pointed out that tobacco production utilized only about 3 percent of the nation's arable land and at peak production the industry employed about 50% of all people employed in commercial agriculture. However, this estimate did not include other activities and downstream industries that exist to service the tobacco industry (ZTA, 2013). Tobacco has also been a springboard for the production of other crops in the country. It is one of the crops with good returns and ready market in Zimbabwe. Income from tobacco is used by growers to develop their farms, cattle production and irrigation schemes. There is therefore no doubt that tobacco is important in Zimbabwe's agriculture and the national economy at large. Consequently, it is therefore vital to continue carrying out research work so that the crop is continuously improved.

Tobacco is an annual, short day and self-pollinated crop which belongs to the family Solanaceae and the genus *Nicotiana* (Hasani *et al.*, 2008). Only two species of this genus (*Nicotianatabacum* L. and *Nicotianarustica L.*) are widely cultivated all over the world (Taj, 1994). Tobacco is one of the few crops entering the world trade entirely on the dry leaf basis and is the most widely grown

commercial non-food plant in the world (Taj, 1994). It is used in the manufacture of cigarettes, cigars and biddies among other products (Taj, 1994).

Due to increased prices of fuel, labor and other inputs, the cost of producing quality flue-cured tobacco has risen. Farmers therefore need to be efficient in their production practices to attain high yields of the quality for maximum profits. Adoption of best management practices (BMPs) is therefore imperative for tobacco farmers to realize the highest profits. This review will therefore focus on nitrogen nutrient management as well as the removal of these priming leaves since these are amongst some of the factors reported to affect yield and quality of tobacco.

2. Trends in Tobacco Production in Zimbabwe

Although Zimbabwe has been reported to be one of the major tobacco producers in the world (TIMB, 2005; FAO, 2011; ZTA, 2013), there has been some fluctuation in the volume of flue-cured tobacco produced and sold in the past two decades (Table 2.2.1). Tobacco production in Zimbabwe increased from 1995 to 2000 when the area harvested increased from 82000 hectares to 92000 hectares with 2000 commercial growers producing 230000 metric tons recorded in the year 2000 (TIMB, 2005). Production decreased in 2001 to 2005 mainly due to the decrease in the area harvested from 72 000 ha to 27 000 ha among other reasons and total yield recorded in 2005 was 55 000 metric tons (FA0, 2011).

YEAR	NUMBER OF GROWERS	AREA PLANTED (HA)	MASS SOLD (Kg)	YIELD PER HA (Kg)	AVERAGE PRICE (US $/Kg)	RETURN PER HA (US $/Ha)
1990	1,493	59,425	133,866,041	2,253	2.61	5,871
1991	1,747	66,927	170,149,851	2,542	3.05	7,757
1992	2,604	80,070	201,161,921	2,512	1.62	4,071
1993	2,999	82,900	218,370,345	2,634	1.24	3,260
1994	2,338	67,417	169,218,196	2,510	1.73	4,331
1995	2,528	74,689	198,751,924	2,661	2.12	5,645
1996	2,917	81,348	201,630,567	2,479	2.94	7,294
1997	5,538	92,117	185,247,898	2,011	2.33	4,694
1998	8,304	95,613	215,983,208	2,259	1.72	3,896
1999	7,192	84,874	192,142,327	2,264	1.74	3,942
2000	8,531	84,893	236,715,481	2,788	1.69	4,713
2001	8,282	75,607	202,445,834	2,678	1.75	4,686
2002	13,400	70,500	165,726,119	2,351	2.27	5,330
2003	19,000	54,000	81,985,625	1,518	2.25	3,416
2004	12,700	41,000	68,784,658	1,678	2.00	3,353
2005	31,000	55,000	73,456,982	1,336	1.61	2,151
2006	15,800	45,000	55,466,979	1,233	2.02	2,490
2007	20,000	50,000	70,467,987	1,409	2.37	3,337
2008	28,000	48,000	48,321,990	1,007	3.21	3,232
2009	20,000	45,000	57,722,483	1,283	2.98	3,823
2010	51,000	67,000	123,458,799	1,843	2.89	5,325
2011	58,000	70,000	132,434,585	1,892	2.73	5,165
2012	67,000	75,000	144,505,678	1,927	3.66	7,053
2013	78,000	88,627	166,572,097	1,879	3.67	6,898
2014	87,000	120,000	216,196,683	1,802	3.16	5.693
2015E	89,000	123,000	190,000,000	1,545	3.20	4.943

Table 1: Zimbabwe flue-cured tobacco production trends from 1990
Source: Zimbabwe Tobacco Association (2014)

The increase in production (from 133,866,041 kg in 1990 to 215,983,208 kg in 1998) could be attributed to the increase in the area harvested and improved agronomic practices in 1998 although the 2001 average yield has yet been reached to date. This implies that there is a lot to be done in improving agronomic practices and area under tobacco production. Poor management of insects, diseases and weeds could also be a major cause of the observed low yields. However, the returns per unit of land have increased significantly since 2011. This shows an improvement in the quality of tobacco that the farmers are now producing. It is clear that the tobacco farmers are now producing better quality tobacco, but the need to continuously improve yield and quality remains.

3. Importance of Tobacco to the Zimbabwean Economy

Zimbabwe is one of the largest producers of unmanufactured tobacco in Africa (ZTA, 2015). However, since the country does not have a very large tobacco manufacturing industry, about 98 percent of the tobacco produced is exported, earning the country millions of dollars which are then used for other developmental activities in the country (ZTA, 2013). Tobacco production makes an important contribution to GDP and to export revenue, and plays a major role in the national economy. The crop normally accounts for more than 59 percent of agricultural exports, 24 percent of total exports and nearly 14 percent of GDP of Zimbabwe (ZTA, 2015). According to FAO (2003), tobacco production is also an important source of government revenue and there is a levy system in which both farmers and buyers pay a fixed percent on the value of crop sales and this generates several million dollars annually.

It is also worth noting that tobacco can grow on some soils, and in certain areas, where other crops cannot grow well (ITGA, 2013). These areas include areas of low fertility and areas characterized by high nutrient leaching. Some tobacco varieties such as the Oriental types, can actually grow in arid areas (ITGA, 2013). These conditions which are invariably not suitable for successful production of other crops make the production of tobacco an important cash crop. Although crops like cotton and maize are more important for most communal and resettlement farmers in Zimbabwe, tobacco offers smallholder growers a unique opportunity for exceptionally high producer profits and excellent rates of return (TIMB, 2005). Tobacco growing is a labor-intensive activity that requires vast expertise. ITGA (2013) has indicated that, the 'know-how' that the tobacco farmers acquire in tobacco growing frequently proves invaluable in the cultivation of other crops.

Tobacco has been reported to fetch very high price stability and higher returns per unit of land (ITGA, 2013). In many areas where tobacco is grown, it has also been reported that crops that are grown after the cultivation of tobacco usually benefit from the residual fertilizers in the soil. The ZTA has also reported that successful production of other crops and animal rearing is often more feasible when a high value crop, such as tobacco, is part of the farming system.

4. Tobacco Yield and Quality

The most important agronomic practices influencing the quality and quantity of tobacco produced by the farmers include nutrient management, especially nitrogen rate and time of application, topping and sucker control with minimal maleic hydrazide (MH) residues, weeding and pest and disease management as well as harvest rate, ripeness and leaf separation by stalk position.

Nutrient management is very crucial in tobacco production. It influences yield and quality to a greater extent (TRB, 2010). In 2010, the Tobacco Research Board (TRB) pointed out that nitrogen is one of the major nutrients that affects and influence tobacco yield and quality. This is in line with a report by Collins and Hawks (1993) who pointed out that nitrogen is the most important plant nutrient in tobacco production. Parker (2009) also confirmed this saying even though nitrogen is not taken up in the highest quantities; it has a more pronounced effect on tobacco growth and quality. Therefore, the amount of nitrogen applied determines the yield and quality of the tobacco the farmer will have (Flower, 1999). Although over application of nitrogen fertilizer may increase the leaf size and the number of leaves per plant and thus increase the yield, it will however, encourage the growth of suckers and thus increase production costs while at the same time reducing the quality of the cured leaf produced (Flower, 1999).

Since tobacco is marketed under contract and auction systems in Zimbabwe, the price paid for that crop will be very low because it will be of inferior quality, mainly due to the effects of excessive nitrogen which affects curing and quality. On the other hand, under-application of nitrogen can result in very low yields of poor quality leaf as well, thus reducing the net income to the grower (Flower, 1999). It is therefore clear that there is need for careful application of the optimum amount of nitrogen to avoid yield or quality penalties which would otherwise negatively affect farmers' income.

Besides nitrogen management, lower leaf harvesting options are other management tools of flue-cured tobacco that are determined by economic considerations. From earlier studies, it has been shown that the lowest leaves (primings) of flue-cured tobacco plant are the lowest in yield and value (Stocks, 1991, Marowa et al., 2015). A lot of management practices have been adopted by farmers when dealing with these lower leaves in a bid to try and improve their profits. Some farmers choose not to harvest them while others prune and discard them because of their relatively low economic return (Stocks, 1991).

There are inherent differences in the agronomic, chemical and mineral characteristics of tobacco leaves depending on where the leaves are positioned on the stalk. Pruning and discarding the primings has been shown by Suggs (1972), Currin and Pitner, (1980) Stocks (1988; 1991) and Marowa et al., (2015) not to adversely affect total yield. However, Court and Hendel (1989) found that if the number of leaves harvested was reduced from 18 to 15 to 12, either by priming or topping to a lower leaf number, total yield was progressively reduced.

In a number of countries where some quotas have been introduced, the objective of leaf harvesting options is to maximize the use of quota by selling the highest quality leaves. This has seen farmers opting not to harvest the lower leaves. By not harvesting lower leaf tobacco, the lowest quality leaves are not marketed (Stocks, 1991) thus benefitting the farmers and the farming sector from maximum economic yield (MEY).

5. Influence of Agronomic Practices on Tobacco Yield and Quality

The physical and chemical properties and yield of leaf tobacco are influenced by several factors which include genetics, agricultural practices, soil type and nutrients, weather conditions, plant disease, stalk position, harvesting and curing procedures (Pandeya*et al*., 2001; Hao*et al.*, 2001; Czuback*et al*., 2012). A change in any of these factors can markedly alter the yield and chemical composition of leaf and thus affect smoking quality and farmer's income (Tso, 1990; Reed *et al*., 2012).

In Zimbabwe, tobacco is marketed under an auction and contract system. Under the auction system, the farmer is paid according to the quality of his produce. However, profitability is directly related to the marketing of quality tobacco produced at the lowest cost. It is also important to bear in mind that quality and quantity is influenced by a number of agronomic practices such as topping height, sucker control, insect pest control and fertilizer level.

6. Nitrogen

Numerous field experiments conducted throughout the world have shown that nitrogen fertilizer is one of the most prevalent elements for plant survival.It is one of the first important growth-limiting factors (Alimohammadi et al., 2011)and an essential macronutrient that can frequently act as a limiting factor for plant growth. Nitrogen is not only an important element for the growth and development of the tobacco plant, but also a major determinant of leaf quality (Zhang et al., 2010). Nitrogen acquisition by plants is usually dominantly by the uptake of ammonium (NH4 +) and nitrate (NO3 -). Soil organic nitrogen can also be taken up by plants and may represent a significant proportion of total N absorption under particular ecological situations such as acidic soils and low temperature environments (Guo et al., 2012).The idea that nitrogen is very important is supported by Parker (2009) who pointed out that nitrogen has a more pronounced effect on the growth and quality of tobacco than any other essential element even though it is not taken up in the highest quantity. Saladin (2006) and Mahmoudi and Hiakimian, (1998) also argued that nitrogen is one of the most important nutrient element because it is part of all proteins, chlorophyll and enzymes.

Although nitrogen has been reported as the major nutrient that affects the tobacco quality and yield (Parker, 2009), nitrogen concentration in the soil has also been reported to fluctuate from near zero to more than 2.5% (Carrow *et al.,* 2001). Carrow *et al*., (2001) further pointed out that the amount of plant available nitrogen depends to a large extent, on the amount of organic matter in the soil. This therefore calls for good management practices to make sure that nitrogen is available in correct quantities at the right time so that a high yield of good quality is produced. The amount of nitrogen taken up and utilized by a plant has also been reported to be dependent on the amount of moisture in the soil (Rathbone, 2008). This therefore supports the idea that irrigation can be used to increase soil moisture levels and thus increase yields (Sifola and Postiglione, 2003). However, nitrogen is very leachable, and over application may contribute to groundwater contamination, thus precision in nitrogen fertilization is the key point to achieve the best yield and quality of tobacco plants.

7. Influence of Nitrogen Fertilizer on Tobacco Yield

In tobacco cultivation, nitrogen is considered a key element that can affect the quality and quantity more than any other nutrients. This has been emphasized by many researches which have pointed out that nitrogen is the most important mineral nutrient affecting the yield and quality of flue-cured tobacco (Elliot, 1975; Collins and Hawks, 1994; Marchetti*et al*., 2006). Virtually most research has shown that tobacco yields increase with increased nitrogen fertilizer (Jones and Tramel, 1979; Aycock and Mckee, 1979; Elliot and Court, 1978; Link and Terrill, 1982; Sifola and Postiglione, 2003; Burns, 1986; Marchetti*et al*., 2006: and MacKown*et al*., 1999). However, research has established that too low rates of nitrogen application result in yield reduction with pale and slick cured leaf, while too high nitrogen may result in slight yield increases which will be accompanied by delayed maturity and extended curing time which resulted in unripe cured leaf (Reddy, 2006) thus increasing production costs with little or no meaningful returns per extra dollar invested (Marowa et al., 2015).

In tobacco production, it is most likely that the bigger the leaves, the greater the yield. Nitrogen has the most profound effect on the development of the flue-cured tobacco plant and generally affects the tobacco yield and quality the most. Peterson (1960) showed that increased nitrogen rates increases the leaf area and the ratio of width to length of individual leaves. However, the dry weight per unit area of the leaf was reduced. Peterson's findings have been supported by Collins and Hawks'(1993) who reported that an increase in the supply of nitrogen from deficient to excessive resulted in an increase in leaf size and decrease body (thickness), while inadequate amount produced smaller leaves of a lower-quality.

Although topping is necessary to maximize leaf production and encourage leaf maturity, nitrogen still remains the major factor influencing tobacco yield (TRB, 2010). Removing the flower switches the plant from a seed producing to a leaf producing phase (Pandeya*et al*., 2001, Wang *et al*., 2012). Topping increases the size and weight of leaves thus increasing the overall yield per hectare but this also depends on the availability of nitrogen to the tobacco plant (Singh *et al*., 2000; Roton*et al*., 2005; Reed *et al*., 2012).

8. Influence of Topping on Tobacco Quality

Tobacco is marketed under the auction system and therefore there is need for one to produce high quality tobacco so that it will fetch very high market prices. Many agronomic practices influence the quality of the tobacco produced by the farmer. Agronomic practices such as topping have been reported by a number of researchers to influence tobacco quality (Singh *et al*., 2000; Roton *et al*., 2005).

Topping stimulates the production of secondary plant products that accumulate in the leaves (Atkinson *et al*., 2002; Yi *et al*., 2006). These products give the cured leaf improved quality and smoking characteristics. Since topping also stimulates sucker growth (Singh *et al*., 2000; Qi *et al*., 2011; Guo*et al*., 2011), a good sucker control program is necessary to ensure high yields of acceptable quality.

Topping has also been reported as the turning point for nicotine formation and accumulation inside the tobacco plant (Roton *et al*., 2005; Guo *et al*., 2011). Nicotine, a secondary metabolite synthesized in tobacco roots, acts as a unique alkaloid in tobacco and is an important quality factor for tobacco. However, before topping the quantity of nicotine formed is relatively small because only about 2.5% of nitrogen (N) absorbed by tobacco plant is used for nicotine formation. After topping, the proportion of N absorbed by tobacco

plant used for nicotine formation goes up drastically, reaching about 16%, resulting in a significant increase of nicotine content in tobacco plant (Leggett *et al*., 1977; Atkinson et al., 2002; Wang *et al.*, 2012).

Although topping stage of tobacco is a key time for development of agricultural measures to promote the quality of leaves (Hao *et al*., 2001; Reed *et al*., 2012), it is clear that nitrogen is the major factor affecting and determining tobacco quality. Even though Amanullah et al., (2008) did not report a statistically significant difference; their data revealed that different nitrogen levels affected the leaf nicotine content. They reported that the highest nicotine content was recorded when N was applied at the highest rate while the least nicotine content was recorded in control plots in their experiments. In their study which is in agreement with those of Cai and Qian (2003), Kena and Kelsa (1990), Sifola *et al.,* (1998) and Sifola and Potiglione (2002), nicotine content showed positive relationship with N levels thus endorsing the idea that nicotine content increases significantly with an increase in nitrogen level (Kena and Kelsa, 1990).However, this increase in nicotine content has been reported to have a negative relation with aroma and taste of tobacco (Kena and Kelsa, 1990).

9. Influence of Nitrogen on Quality of Tobacco

Nitrogen level does not only affect nicotine content. Research has shown that N level has an effect on reducing sugars in tobacco. Amanullah et al., (2008) showed that, different N levels have significant effect on the leaf reducing sugar. They noted that leaf reducing sugar was negatively related to N levels. Amanullah and colleagues (2008) reported that the highest level of reducing sugars was observed in the control plot while minimum reducing sugar was obtained when N was applied at the highest rate of 50 kg ha. Their results are in agreement to those reported by Cai and Qian (2003) who observed significant reduction in reducing sugar in the leaves of tobacco when N rate was increased. However, earlier studies by He and Sun (1991) found no significant effect of nitrogen on the reducing sugar content in tobacco which therefore calls for further investigation in this area. This also shows that there is need to establish the optimum N level, which will result in the desired levels of both nicotine and reducing sugars.

Parker (2009) pointed out that the role of nitrogen in the development and quality of tobacco is of major importance. Soil nitrogen must therefore be sufficient during early and mid-season growth stages to ensure a vigorous, but not excessive plant growth. Nitrogen should also be nearly depleted by the time of flowering for the tobacco to mature and ripen properly ensuring a quality leaf. In general, as total N in the plant increases above the amount required for maximum growth, quality of flue-cured tobacco tends to decrease.

Non-optimal levels of nitrogen adversely affect tobacco, particularly on the yield quality of cured leaves, which has been reported to show unbalanced chemical properties are generally non marketable characteristics (Kena and Kelsa, 1990). It has been noted that insufficient nitrogen produces small, thin, narrow, smooth, and pale leaves that often require harvest before they have fully ripened (Weybrew*et al*., 1983). The cured leaves are pale, lack texture, and the smoke is flat and insipid. On the other hand, excess nitrogen produces rough, large and thin leaves. However, their ripening is delayed and curing is difficult. The cured leaf color is dark and the smoke is strong and pungent (Weybrew *et al*., 1983; Maw *et al*., 1995).

It is therefore clear that nitrogen plays a very important role in the quality and quantity of tobacco. Application of nitrogen has been shown to increase leaf number, leaf area and nicotine content (Ahmad *et al* 1990; Sifola and Postiglione, 2002). Although an increase in nitrogen level is associated with an increase in nicotine content, it is also associated with an increase in the concentration of tar in tobacco (Sifola and Postiglione, 2002) thus there is need to determine the optimum N level which will produce desired nicotine and tar concentration. Yield, production value and the contents of nicotine, potassium oxide and total N of the cured leaves is positively correlated to the amount of N application and significantly and negatively correlated to the percentage of superior-medium class leaves of tobacco and contents of deoxidize sugar. Zhang et al., (2010) concluded that high quality tobacco leaves which fetched higher average market prices and had reasonable chemical constituents were harvested after the application of 45 kg N per hector rather than after the application of 60 or 75 kg N per ha. This supports the idea that although high levels of N can increase the yield, it has a negative effect on the quality. However, the amount of N applied varies spatially.

10. Primings

Primings are leaves on a tobacco plant that are located closest to the ground. They are sometimes referred to as sand leaves or mud lugs. These leaves are of poor quality and because of their proximity to the ground; they often come in contact with sand and soil and consequently, must be cleaned before they can be processed (TRB, 2014). Tobacco production, unlike that of most other agronomic crops, involves harvesting of the vegetative tissue (leaves) and not the reproductive tissue (seed). Flue-cured tobacco leaves, unlike most other tobacco types are harvested manually or mechanically as the leaves mature on the plant. Harvesting of the flue-cured tobacco progresses with maturity from the lowest to the highest leaves on the plant stalk. This harvest method allows all leaves to become fully mature if proper production practices are followed. With most other tobacco types, the entire plant is severed in the field at a stage when a majority of the leaves on the plant is judged to be mature. However, the lowest leaves, primings, have been reported to be of inferior quality as has been explained above.

Although the progressive harvesting of flue-cured tobacco results in mature leaves, there are considerable physical and chemical differences depending on the position or node at which the leaves are formed on the stalk (leaf position). Leaf position is of considerable importance in the tobacco industry. Tobacco is marketed, graded and sold according to leaf position regardless of type. Tobacco products are also manufactured based on certain characteristic properties of the cured leaf which in turn is influenced most by leaf position (Weybrew *et al.,* 1984).

According to North Carolina (2015), tobacco leaves have specific names depending on their stalk positions. For flue-cured tobacco, it consists of the primings, lugs, cutters, leaf and the tips (Figure 1). Primings are lower leaves on a tobacco plant which often come in contact with soil. According to the 2013 North Carolina Flue-Cured tobacco guide, the primings are the first leaves to ripen and to be harvested. They make up 12% of the total plant weight and contain 1.5% to 2% nicotine and 5% to 11% sugars respectively. The guide also points out that the lugs are thin, blunt-tipped leaves around the bottom of the stalk making up 13% of the plant's weight and contains about 2.5% nicotine and 12% to 20% sugars. The cutters are the largest leaves on the plant while the leaf makes up to 34.5% of the plant. They contain 2.5% nicotine and 12% to 22% sugars and 3.5% nicotine and up to 15% sugars respectively. The smoking leaves are just above the stalk middle, are thinner than the "bodied" leaves above them, and their tips are less pointed. About 7.5% of the plant, smoking leaf ripens to a rich orange color and contains about 3% nicotine and 12% to 20% sugars while the tips are at the stalk top making up around 18% of the plant's total weight. Tip leaves are narrow and pointed, smaller than lower leaves, yet thicker and more full bodied. Tips of flue-cured tobaccos contain from 3% to 3.5% nicotine and 6% to 6.5% sugars (North Carolina, 2013).

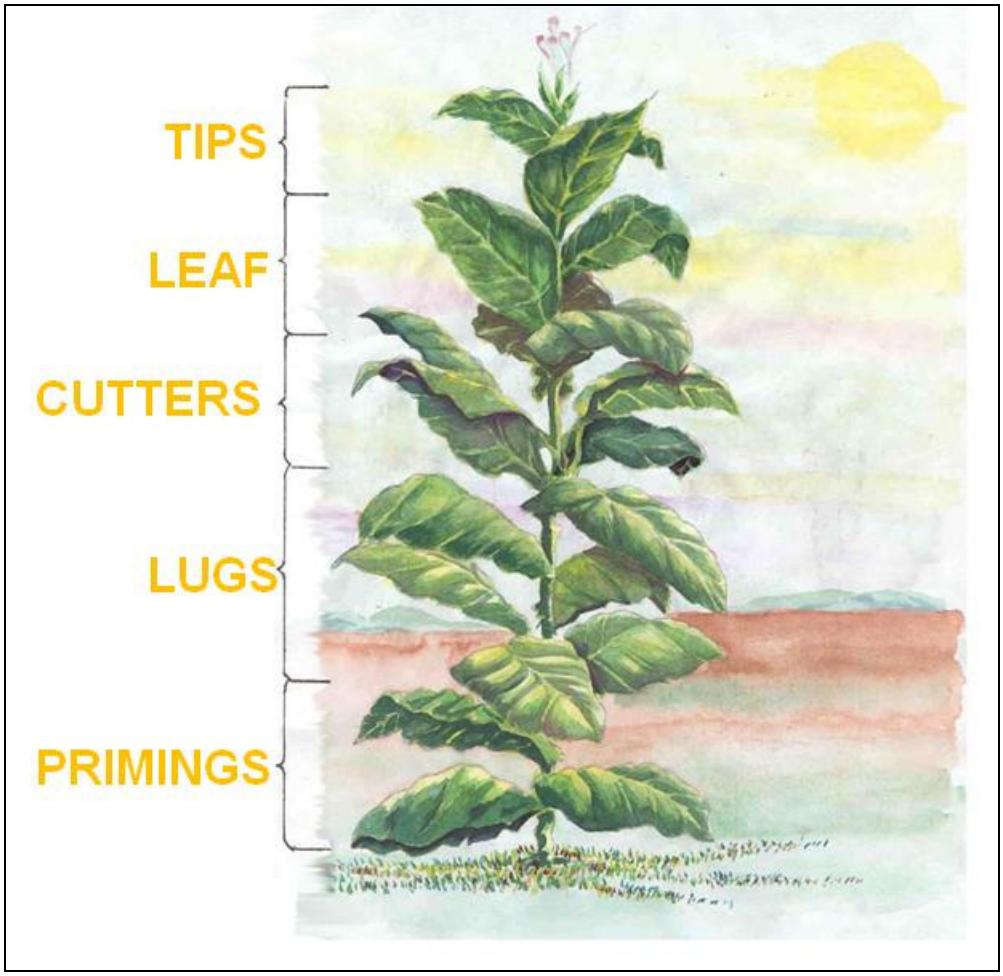

Figure 1: Structure of flue-cured tobacco plant (North Carolina, 2013)

Over 2500 chemical compounds have been identified in the leaves of commercially grown tobacco and the most important of these is nicotine. It is however important to realize that various sugar levels found in the plant play a vital role when different tobaccos are blended. Nicotine and sugars in the leaves vary according to soil type, moisture and agronomic practices.

11. Influence of Priming Leaf Removal on Tobacco Yield and Quality

The removal of primings from the tobacco plants in the field can improve the yield and quality of the harvested tobacco leaves, especially that of the first reaping (Marowa et al., 2015). Farmers have reported that primings are difficult to work with and that they usually have sand or mud on them. At times there will be need to clean them before they can be cured. However, these primings which normally constitute the bulk of the first reaping, when they are not removed, usually fetch the least price on the market due to their poor quality.

Data from previous studies dealing with lower leaf harvesting options for flue-cured tobacco suggests that pruning and discarding a number of leaves did not adversely affect total yield, but improved the averaged value per kilogram when compared to harvesting all leaves (Suggs, 1972; Currin and Pitner, 1980; Stocks, 1988, Marowa et al., 2015). Along with low demand due to the poor flavor contribution and quality, lower-leaf stalk positions also contribute the least to overall yield. Brown and Terril (1972) determined the

relative yield for a twenty-leaf plant by stalk position. From the lowest stalk position to the highest, in four leaf increments, relative yield was 12.6%, 20.2%, 25.1%, 23.2%, and 18.2% respectively. The lowest stalk position (the bottom four leaves) contributed the least to overall yield. White and Matzinger (1960) also reported that relative yield generally increased with higher stalk positions.

Due to the need to provide a blend desired by the consumer, high-quality leaf is desired by the tobacco industry. High-quality leaf is key to blending the desired taste and it generally comes from the upper-stalk regions of the plant. Other than a good filling value, which is the amount of tobacco occupying a given space, leaves from lower stalk positions contribute very little to a blended product. Primings and lugs offer the least flavor contribution and have the lowest nicotine content among all stalk positions (Fisher, 1999). The cutter stalk position is generally used as a modifier, but only a ripe cutter grade can impart some flavor contribution (Fisher, 1999).

Due to the low relative yields and less desirable chemical qualities in tobacco leaves from the lower stalk positions, a number of lower-leaf removal studies have been conducted. In the 1970's, lower leaf positions were in less demand resulting in research on the removal of the bottom four leaves and higher topping to provide the addition of four upper-stalk leaves on non-flowering varieties (Collins and Hawks, 1993). Court and Hendel (1989) showed that lower-leaf removal had a negative impact on yield when addition of upper-stalk leaves was not imposed while differences in total alkaloids and reducing sugars were not significant. Thus, the addition of upper-stalk leaves when removing lower leaves may be necessary to achieve desirable yields. Black (1981) also studied the removal of lower leaves and addition of upper-stalk leaves with mammoth (photoperiod-sensitive) cultivars and concluded that the addition of six upper-stalk leaves tended to overcompensate for the weight of the four leaves discarded from the bottom of the plant. However, the removal of less desirable lower-stalk, leaves without the addition of upper-stalk leaves resulted in decreased yield.

In another study by Edwards (2005), removal of lower leaves at the early flowering stage with the assumption that weight would be shifted to higher stalk positions to moderate potential yield loss proved to be false. Edwards (2005) found out that removing four leaves resulted in a nine percent yield decrease and an eleven percent value per hectare loss compared to a 23% yield and 22% value per hectare loss when eight leaves were removed. He further noted that, removing four leaves resulted in a four percent yield and five percent value per hectare loss compared to a 21% yield and 20% value per hectare loss when eight leaves were removed.

Edwards (2005) pointed out that one of the potential impacts of lower-leaf removal would be an increase in average price due to a shifting of grade distribution to upper-stalk grades. He reiterated that such an increase would compensate for yield loss. However, increases in grade index and price per kilogram were small with the leaf removal treatments and showed a lack of consistency. Compared to the controls in the Edwards' study, removing leaves from lower stalk positions, whether four or eight, improved the grade index, price per kilogram, and saved about $400 in harvesting/handling labor, curing fuel, and electricity costs. However, this did not sufficiently compensate for the 20 percent or more yield and value loss per hectare. Edwards (2005) therefore concluded that since removing four or eight leaves did not statistically decrease or eliminate lug grades, other factors should be studied for their effect on grade distribution and reduced quality of leaves.

His conclusion might be one of the reasons why Marowa et al., (2015) decided to combine the removal of lower leaves and the addition of an extra nitrogen above the recommended rate. These researchers went on to report that removal of priming leaves combined with the addition of supplementary nitrogen neither increased leaf expansion nor lowered the yield. They, however, demonstrated that if these leaves are removed, followed by an appropriate fertilizer regime, farmers are able to benefit more from the reduced production and handling costs (Table 1). Basing on the gross margin of the expanded project, Marowa et al., (2015) they concluded that farmers would also benefit from high quality first reaping that will fetch very high prices on the market.

12. Conclusion and Future Prospects

Good progress has been made regarding the development of best tobacco management practices with the aim of achieving maximum economic yields. This paper has reviewed how manipulation of simple agronomic practices improves the yield, quality and consequently returns. However, there is still need to establish the best nitrogen and priming levels, which might vary with place and variety.

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