EFFECTS OF INTRA ROW SPACING ON GROWTH, YIELD AND QUALITY OF SELECTED NEW FLUE CURED TOBACCO *(Nicotiana tabacum L.)* VARIETIES

BY

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A research project submitted in partial fulfilment of the requirements for the Bachelor of Science Agronomy Honours Degree

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DECLARATION

I hereby declare that this dissertation has been the result of my own original efforts and investigations, and such work has not been presented elsewhere for any degree. All additional sources of information have been acknowledged by means of references.

Signature................................. **Date...**

CERTIFICATION OF THESIS WORK

I, the undersigned, certify that Onias Mlambo**,** a candidate for the Bachelor of Science Agronomy Honours Degree has presented this dissertation with the title:

EFFECTS OF INTRA ROW SPACING ON GROWTH YIELD AND QUALITY OF SELECTED NEW FLUE CURED TOBACCO VARIETIES (*Nicotiana tabacum L.)*

That the dissertation is acceptable in form and content, that satisfactory knowledge of the field covered by the dissertation was demonstrated by the candidate through oral examination held on **05/05/2015**.

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ABSTRACT

Tobacco is an important cash crop contributing significantly to the Zimbabwean economy. However yield and quality remain very low in the small holder sector despite the availability of potentially high yielding varieties. There are various factors which contribute to lower yields some of which are poor plant spacing combinations which result in either intra specific or inter specific competition. Intra row spacing has the potential to improve yield and quality of the tobacco if properly done, since it has been shown to have greater contribution to competition. Inappropriate intra row spacing particularly the intra row can result in yield and quality penalties. Studies indicate that 35 % of the smallholder farmers are using inappropriate spatial arrangements with a decrease in the intra row spacing in particular. This has been highlighted as a potential yield and quality limiting factor. Higher yielding varieties were also released to improve productivity of the farmers. Three varieties were also released namely T 70, T74 and T76, however their spatial arrangements were not established hence the need to evaluate their spatial arrangements particularly the intra row spacing. A field experiment was conducted to evaluate the effects of intra row spacing on growth, yield and quality of tobacco varieties KRK 26, T70, T 74 and T 76 at Kutsaga Research station. Sixteen treatments comprising four levels of the variety which was the main pot factor and four levels of the intra row spacings which was the sub plot factor were used in a 4 x 4 split plot arrangement in an RCBD with three replications. Assessment for growth, yield and quality parameters was done for leaf expansion, stalk height, saleable yield, grade index and sugar to nicotine ratios. There was an interaction amongst intra row spacing and variety on stalk height, leaf expansion, saleable yield, percentage grade index and sugar to nicotine ratios. Stalk height and leaf geometric mean were statistically higher at wider spacings than at closer spacings for all the varieties. Saleable yield and grade index was statistically higher for all the varieties at wider spacings compared to closer spacings. Desired ratios of sugar to nicotine content were obtained at wider spacings, while at closer spacings ratios surpassed the desired ratios for varieties such as T 74 and T76. It was shown that intra row spacing improved the performance of all the varieties used in this study. Increasing intra row spacing from the recommended spacing of 56 centimetres showed significant improvement for all the parameters assessed in this study except stalk height. The older variety improvement specifically in the quality attributes at wider spacings. Farmers may consider the use of wider spacings of 66 and 76 centimetres to improve yield and quality of their produce for all the tobacco varieties used in this study.

DEDICATION

To my sisters Tanatsiwa and Tavimbanashe

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ACRONYMS AND ABBREVIATIONS

AN	Ammonium Nitrate
ATP	Adenosine Triphosphate
CV	Co-efficient of variance
EC	Emulsifiable Concentrate
GDP	Gross Domestic Product
KM	Kutsaga Mamoth
KRK	Kutsaga Root Knot
LSD	Least Significant Difference
LSD	Least significant difference
MG	Mamoth Growth
NUE	Nitrogen Use Efficiency
RCBD	Randomised Complete Block Design
TIMB	Tobacco Industry and Marketing Board
TRB	Tobacco Research Station
WAP	Weeks after Planting

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CHAPTER 1

1.0 INTRODUCTION

1.1 BACKGROUND AND JUSTIFICATION

Tobacco (*Nicotiana tabacum* L.*)* is a high value crop whose production dates back to the colonial era in Zimbabwe (Mazarura, 2004). It is the backbone of commercial agriculture in Zimbabwe since it is a high value crop contributing significantly to the Gross Domestic Product (GDP) of the economy *(*Mutsakani, 2004*).* Tobacco is grown for its leaf where nicotine the major economic product of tobacco that is extracted, (Mazarura, 2004*).*

Despite the economic importance of tobacco and its contribution to GDP the yield per hectare still remains very low due to several factors. The national average yield is between 1-1.3 tonnes per hectare compared to 2.5-5 tonnes per hectare potential (TRB, 2012). The small holder farming sector contributes more to the lower national potential average yield compared to the commercial sector which tends to improve the national average yield. Studies have shown that the low yield per hectare that is being obtained in the small holder farming sector is particularly a result of the poor agronomic practices employed by the small holder farmers (TRB, 2012). Studies further indicated that these poor agronomic practices have a major bearing on the quality of the produce as well and since tobacco is sold through the auction system, this has a bearing on the profitability of the farmers (TIMB, 2013). Amongst the poor cultural practices are late topping and desuckering due to labour shortages (Mazarura, 2004). In addition to that improper nutrition is also a challenge due to inadequate application of fertilisers as a result of the higher costs of fertilisers on the market therefore affecting quality of the leaves produced, also poor weed control strategies are also employed by small holder farmers and this is critical since weeds have been shown to have potential to reduce yield by up to 50% (Katahari *et a.,l* 1999). Another improper practice employed by farmers is the delay and inappropriate pest management for economically important pests. Overall poor productivity has been highlighted to revolve around poor agronomic practices mainly due to lack of inputs.

Therefore this calls for other viable and non monetary agronomic considerations that have the potential to boost productivity and also improve product quality. One such option that has been availed to the farmers in the past few years is the use of high yielding varieties. Many new varieties has been released for example KRK66, KRK71, KRK72 and KRK64 all of which has been grown for quite a number of seasons now but with no significant yield improvement (Mudzengerere, 2013). Currently there are three more pre-released high yielding varieties that are still under agronomic evaluation at Kutsaga namely T70, T 74 and T 76. Despite the release of these varieties, yield and quality remains below par. It has been highlighted by Mazarura (2004) that, evaluations for agronomic practices has been done using the less yielding KE1 and KM10 estimated at 1.5 to 2.5 as compared to most new varieties which range from 3.5 to 5 tonnes per hectare. The author also indicated that evaluations for all the varieties that were released over the past ten years centred most on issues to do with plant diseases and insects (plant health). However according (Copper, 2010) stated that different varieties with different growth characteristics and morphology require different agronomic practices to fully express their yield potential.

Studies have indicated improper spatial arrangements particularly the intra row spacing as another critically important factor that is limiting productivity by small holder farmers. Research has shown that 35 % of small holder farmers are using narrower spatial arrangements specifically the intra row going for narrower intra row spacings of as low as 45 centimetres or less against the recommended intra row spacing of 55 centimetres and this has been shown to have yield and quality limiting effects (Mudzengerere, 2013). However the current recommended intra row spacing was developed using mammoth varieties which tend to differ in morphology and physiology with the recently developed varieties. According to (Mudzengerere, 2013) indicated the intra row spacing as the most changed aspect of spatial arrangements by farmers and highlighted that this is because inter row is difficult to change due to the fact that it is governed by available machinery. Generally spatial arrangements refer to both the inter row and the intra row spacing.

Studies have shown that intra row spacing is of particular importance as it contributes more to crop to crop competition (Copper, 2010). This explains why changes in intra row spacing cause much significant changes in yield and quality than inter row. Therefore it is recommended that in any evaluation of plant spacing intra row spacing must be treated with much more attention and precision than inter row. According to Copper (2010) several studies on Burley tobacco have indicated that yield can be increased by growing crops in narrow intra rows, provided there is no intense competition of growth factors such as water and soil nutrients. Studies have indicated that narrow intra row spacings have various advantages for example more plants per unit area and therefore more green leaf yield per unit area (Katahari et *al*., 1999).

Wider intra row spacing of tobacco plants can also on the other hand result in improvement of leaf expansion, nicotine content and sugar levels. Wide intra row spacing is associated with low intra specific crop competition for resource and therefore resultant crop stands are heavy bodied having a higher proportion of upper grade standard leaves increases and thus improving cured leaf quality (Svotwa *et al*., 2013). Studies has shown that wider spacing in tobacco result in more weed pressure due to the creation of bare spaces in between plants promoting weed to crop competition. Conclusively there is need to evaluate agronomic practices for the new pre-released varieties, and there is also need to evaluate proper spatial arrangements for the highly yielding varieties and come up with proper high yielding spatial arrangements or yield improvement. Therefore this study reported here aims to evaluate the effects of intra row spacing on growth yield and quality of selected new flue cured high yielding tobacco varieties.

1.1 OVERALLOBJECTIVE

To determine the effects of intra row spacing on growth, yield and quality of selected new flue cured tobacco varieties.

1.2. SPECIFIC OBJECTIVES

1.2.1 To determine the effect of intra row spacing on plant height and leaf geometric mean of tobacco varieties

1.2.2 To determine the effect of intra row spacing on saleable yield, nicotine content, sugar level and grade index of tobacco varieties

1.3. HYPOTHESES

1.3.1 Plant intra row spacing and variety have significant effect on plant height and leaf geometric mean of tobacco.

1.3.2 Plant spacing and variety have significant effect on saleable yield, nicotine content; sugar level and percentage grade indices of tobacco.

CHAPTER TWO

2.0 LITERATURE REVI EW

2.1 ECONOMIC IMPORTANCE OF TOBACCO IN ZIMBABWE

Zimbabwe is the fourth largest producer of tobacco *(Nicotiana tabacum)* after Brazil, China and India. In 2014, average annual exports of tobacco in Zimbabwe were 190 000 tonnes with a total average export revenue of US$604.7 million. Tobacco has been the largest single export crop in recent decades. The crop normally accounts for more than 10% Gross Domestic profit (GDP) of the Zimbabwean economy (TIMB, 2013). Zimbabwe had established an international reputation of producing a high quality crop and high nicotine content that compete favourably on the world market; however the trend is declining in terms of the quality of the produce. The Chinese buy about 40 percent of Zimbabwe's tobacco and Western Europeans about 35 % of the golden leaf. Tobacco is used in food processing industry, cosmetic industry, chemical industry, pharmacy and mainly in tobacco industry (Kulic *et al*., 2008).

2.2 CHALLENGES OF TOBACCO PRODUCTION IN ZIMBABWE

Despite the economic importance of tobacco in Zimbabwe, the industry faces a number of challenges that include high costs of fertilizers, leading to under application of fertilizers such as ammonium nitrate or calcium nitrate and this compromises quality and yield of tobacco. Inadequate nitrogen supply result in production of smaller and paler leaves of poor quality (Collins et *al*., 2011). Weed infestation is another challenge faced by farmers with the most problematic one being the witch weeds, (*strigga gesenariotes)* because it is difficult to control the weed mechanically as it a parasitic weed and tends to be attached to the roots of the tobacco extracting nutrients and water at the expense of the crop for survival (TRB,2013).

Weeds compete fairly well with crops for resources and therefore reduce productivity if proper weed control strategies are not implemented. Weed control is critical as highlighted by (Koga, 2007) that competition from weeds alone can result in 50% reduction in yield.

Despite the increase in the area under cultivation of tobacco as well as number of growers yield per hectare continues to go down due to quite a number of factors among them the issue of improper spatial arrangement specifically the intra row spacing of the crop in the field. Farmers readily try non monetary options for yield and quality improvement (Yemanne, 2013). This has led to availability of such options and one good example of such options is the release of high yielding and multi-disease resistant varieties over the past few years. Some of the higher yielding varieties include T71, T72 KRK66 s well as the pre-released varieties which are T70, T74 and T76. However treatment of the released varieties with no consideration for their morphological differences might be a major reason for failure to realize their optimum productivity.

Varietal considerations must be in the form of application of suitable agronomic practices to allow expression of their full potential for yield and quality. Due to the realization that reduction in intra row spacing can be such an option it has led to various intra row spacings being tried in arable fields with quite a number of farmers across the country in tobacco growing areas. Results were unbearable since further yield decline were witnessed by most farmers (TRB, 2013). This has also resulted in the production of small, poor quality leaves fetching as low as US$0.60 per kilogram for the worst grades rather than US$3.50 up to US$4.99 per kilogram for the best grades. This is because inappropriate spacing was used and besides yield reduction, tobacco quality was also compromised due to inappropriate intra row spacing. Therefore there is a need to evaluate the appropriate spatial arrangements for improvement of yield and quality as well as the full expression of the potential of new and pre-released varieties.

2.3 EFFECTS OF INTRA ROW SPACING AND VARIETY ON STALK HEIGHT OF TOBACCO

Research has shown that stalk height is mostly determined by light competition and nutrients availability (Mudzengerere, 2013). Generally, tobacco plants from wider spaced intra row spacing are characterised by normal or average stalk heights of usually 75 to 100 centimetres though this may depend on the variety, also plant height is mainly determined by genetic characteristics and light requirements (Wu, 1999). The author also pointed out that this is due to reduced crop to crop competition for light and nutrients. Mudzengerere (2013) postulated that closely spaced plants usually channel assimilates to stalk height at the expense of other yield components such as leaves. The author also indicated that competition for light is the most critical factor than root competition. Katahari (2000) indicated that the response of competing plants to light is usually taller and thinner plants which are at higher risk of lodging. In a study with KM10 and MG varieties, it was shown that at closer inter and intra row spacings KM10 resulted in higher stalk height as compared to MG varieties but as intra row spacing widened stalk heights for both varieties declined significantly. It was concluded that higher stalk heights obtained were merely due to competition and more competition by KM10 at closer spacings were attributed to varietal morphology. It is therefore important to suit proper spacings to varietal morphological differences for optimum productivity.

2.4 EFFECT OF INTRA ROW SPACING AND VARIETY ON LEAF GEOMETRIC MEAN/LEAF EXPANSION OF TOBACCO

Geometric mean leaf area is calculated from the square root of the product of leaf length and leaf width (Svotwa et *al*., 2013). Geometric mean leaf area is sufficient in explaining changes in tobacco crop canopy. According to Wu (1999) indices that summarize crop canopy dynamics based on the photosynthetic area available such as leaf area index tend to become less predictive as canopies become denser and therefore leaf geometric mean can be more reflective. Closer spacing of plants in Zimbabwean tobacco crop productivity tobacco refers to intra row spacings that are less than 56 centimetres (TRB, 2012). Such spacings usually result in a reduction in leaf length and width and therefore leaf geometric mean, texture and weight (Tso, 1999). This is because of more crop to crop resource competition on closer spaced plants than on wider spaced plants. Due to this competition it results in limited resources being available for individual plants such that vegetative growth is negatively affected. Generally for crops to attain maximum vegetative growth they need adequate water and nutrients and if these resources are limiting the response is usually stunted growth, or general reduction in crop growth parameters such as leaves, sometimes stalk height and root development.

Competing plants tend to produce smaller leaf sizes and this is critical since the leaves are the photosynthesising part of crop plants. Leaf measurements taken from a field in which there are competing plants usually give lower leaf expansion capacities which translates to low geometric mean values (Collins et *al.*, 2011). However competition is directly linked to differences in varietal morphology in that some varieties are generally small statured and the proportion of upper standard leaves is usually low as compared to the other varieties which are gigantic statured, having a massive proportion of upper standard leaves. This means that competition differs in such scenarios with small statured varieties having low competition as compared to gigantic varieties at any given intra row spacing or even intra row spacing. In addition to that due to differences in leaf expansion capacities as well as overall stature/morphology there are marked differences in terms of response to intra row spacings. Research that has been done with most annual crop have shown that resource competition limits yield in that the chief photosynthesising tools which are the leaves fail to fully expand

and any growth assessment analysis involving it tends to indicate lower than expected values for example leaf area index or leaf geometric mean values (Ranna and Ranna, 2014).

2.5 EFFECT OF INTRA ROW SPACING AND VARIETY ON SALEABLE YIELD OF TOBACCO

Saleable yield of the flue cured tobacco leaves is generally higher for those plants that are grown at wider spacing (Kutjevo, 2005). Wider spacing in tobacco production generally result in negligible or no competition for resources between plants therefore allowing more assimilates to accumulate in leaves thus more biomass which translates to the actual final cured leaf mass (Kozumplik and Lamarre1979). Narrower spacings tends to limit leaf expansion o the crops and therefore smaller leaf sizes result in reduced efficiency of photosynthesis and therefore biomass accumulation and finally the yields, however response to competition tends to vary due to differences in varietal morphology and physiology. Studies have shown that intra row spacing plays an important row in plant-plant variability in growth rate and weight frequency distribution (Weiner and Thomas, 2002).

Competition for light is more prevalent in narrow intra row spacings than wider ones because proportion of plants per unit area will be higher and each of the plants will be requiring more light for photosynthesis and this is critically important in that light is responsible for the production of ATP and NADPH and thus it becomes less available, leading to low light intensities and these products are not produced in adequate amounts (Randel, 2010). These are important products of the Calvin cycle of photosynthesis so inadequate production will lead to inefficient photosynthesis and therefore low assimilate partitioning and biomass accumulation. Since the leaves in tobacco are the harvestable portions they are the ones that usually suffer reduced accumulation of assimilates and the result is the production of leaves of lighter mass.

High photosynthetic assimilates are channelled to leaf production when there are no stresses or resource competition. When there is resource competition, assimilates are channelled in the production of structures such that the crop will compete and survive on the limited resource, such as long extensive root system. This is linked to plant intra row spacing since it has more pronounced effects on resource competition (Silverton, 2011). This means that the harvestable parts in this case the leaves also suffers and are unable to have optimum production.

Masuka (2011) found out that very closely spaced tobacco plants usually produce many leaves of lighter mass due to massive competition of water and nutrients. Since plants respond differently to poor nutrition competition for light and water may either be reduced or be amplified by a shortage of nutrients (Carmel, 1983). Competition as a result of plant spacing specifically intra row occurs in two ways, the symmetrical and the asymmetrical.

Asymmetrical competition occurs when few plants of a large population utilises a disproportionately large share of the available resource to the detriment of the growth of neighbour plants (Fisher et al., 2006). In general asymmetrical competition results in variation in biomass production, and however there are complex interaction, between the nature of the resource, the plant intra row spacing, the episodic availability of the resource, the spatial heterogeneity of the resource, and the plant's physiological and morphological response to levels of resource supply (Schwinning and Weiner, 1998).

All these factors increase the chances of asymmetrical competition. Wider spacing reduces intra specific competition of resources with other crops. Razelly (2002) showed that with the flue cured tobacco cultivar W113, there was a marked increase in saleable yield with leaves taken from wider spaced intra rows than from closer spaced ones. Also Masuka (2012) showed that responses to different intra row spacings with MG variety and KM10 variety in terms of the saleable yield was different, with more saleable yield obtained from wider spaced plants than closer spaced ones. The differences were attributed to resource competition as well as varietal morphological and physiological characteristics. The major environmental factors in intra specific competition are light, water, space and mineral nutrients (Fehr and Caviness, 1999).

2.6 EFFECT OF INTRA ROW SPACING AND VARIETY ON NICOTINE CONTENT OF FLUE CURED TOBACCO LEAVES

Chemical analysis in a similar study revealed slightly increased nicotine and reducing sugar content of cured leaf from the wider plant spacing. Also Collins and Hawks (1993) reported a reduction of alkaloid content as plant intra row spacing was reduced. It is important that leaf composition in tobacco has been shown to greatly vary according to differences in plant spacing and other growing practices. Closely spaced plants produce low nicotine content because of competition for nitrogen and since nitrogen is a key determinant factor determining nicotine content (Cristanini, 2006). Increasing or decreasing leaf number per hectare has also been shown to alter leaf quality by modifying the levels of alkaloids such as nicotine, in that closer spaced plants generally result in low nicotine levels due to small area of nicotine accumulation. This is because nicotine is produced in the root tips (Katahari, 1999) and transported through the xylem vessels and stored in the leaf (sinks) so leaf nicotine levels tends to directly vary according to leaf geometric mean. Abdullar (2000) described the required limit of nicotine for high quality cured tobacco leaves as between 2.5 to 3.5 % of dry weight.

Wider spacings result in produced plants having higher nicotine content due to significant reduction in intra specific competition for nutrients such as nitrogen (Elliot, 1990). The physical and chemical properties of tobacco are regulated by genetics and by total growth environment (Sohel and Sidique 2009). Generally leaves of crop plants taken from wider spatial arrangements particularly wider intra rows contain desired levels of nicotine because of appropriate sink size.

2.7 EFFECTS OF INTRA ROW SPACING AND VARIETY ON SUGAR LEVELS AND NICOTINE TO SUGAR CONTENT RATIOS IN TOBACCO

Levels of sugars tend to depend or to vary on the level of nicotine in the tobacco leaves (Yemmanne, 2013). Sugar content is inversely proportional to nitrogen availability. So in closer spaced plants because of competition for the mobile nitrogen nutrient, it becomes inadequately available and therefore resulting in low nicotine content levels and for the wider intra row spacings there is little or no competition for nitrogen such that it is available and this translates to higher levels of nicotine in the leaves (Yemmanne, 2013). However fluctuations in the level of nicotine in the leaves have got a bearing on the level of sugars or the ratio of sugars to nicotine. According to Raper and McCants (2006), they concluded that low or inadequate nitrogen causes plants to synthesize starch prematurely and thus restricting nicotine production and favors starch accumulation.

Tobacco with a higher percentage of sugars is unbalanced chemically with sugar/nicotine ratio greater than nine and they produce a flat insipid smoke. There should be a chemical balance between sugar and nicotine levels. As the nitrogen availability increases there is usually a subsequent decrease in the sugar to nicotine ratio due to increased synthesis of nicotine. This is attributed to the fact that nitrogen is a component of the nicotine molecule so when it is available in the soil more nicotine will be produced in the plant hence reduction in the ratio. According to Tobacco Industry and Marketing Board (2013) the recommended sugar to nicotine ratio is in the range of 6:1 to 9:1. Any leaf out of this range is considered to be of poor quality. In Addition to that it has been shown that variations in leaf sugar to nicotine levels can depend greatly on varieties in that some varieties due to their nitrogen use efficiency, they usually produce desired levels of nicotine than others and therefore accumulate more nicotine in the leaves thus reducing the ratios. While some varieties due to their poor nitrogen use efficiencies they tend to accumulate lower levels of nicotine and therefore produce more starch and sugars and thus increasing the ratios.

2.8 EFFECT OF INTRA ROW SPACING AND VARIETY OF TOBACCO GRADE INDICES

The grading system plays a crucial role in the blending process (secondary tobacco processing) in ensuring that the leaves of the right type and quality are used to achieve the tastes and aromas in cigarette production (Phillip Morris International, 2002). Tobacco quality evaluation is categorised as internal or external, where the former is achieved through the use of smoking test or chemical composition analysis and the latter is mainly attained through human vision where the features evaluated include colour, maturity, surface texture, size and shape of the leaf (Zhang and Zhang, 2011). Intra row spacing can influence tobacco quality for instance with reduced intra rows there is usually low nicotine accumulation in the leaves and this results in more starch accumulation leading to undesired or chemical imbalance between the two components. This has got a bearing on leaf quality in that leaves with more starch are usually thicker and rough and since grading considers leaf texture this may reduce overall grade.

Leaf size is also very important in determining grade index because smaller leaf sizes usually result in lower grades since leaf size is the first aspect to consider on cured leaf quality. Small leaf sizes are usually of lower quality and poor grades while large leaf sizes usually result in higher quality and better grades. Furthermore leaf size is greatly affected on closer intra row spacings because generally closer intra rows result in the production of paler and smaller leaves, while wider spaced plants usually produce bigger sized leaves which translate to higher grades. Lodging is also associated with closer spaced plants and this may result in leaf damages and this has got a bearing on grade indices since physical appearance is an important component in the tobacco grading system. However variations in leaf size and colour are also variety dependent besides agronomic practices such as intra row spacing.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of study site

The study was carried out at Kutsaga Research Station. Kutsaga lies in Natural Region IIa (Agritex, 2005; Vincent and Thomas, 2004) at an altitude of 1 479 metres above sea level (Akehurst, 2009). Geographically, the site is found on latitude 17^{o} 55\`S, longitude 31$^{o}$ 08\`E (FAO, 2006). Mean annual rainfall varies between 800-1000mm and normally falls from November to March (Rukuni and Eicher, 2006). Average temperature in summer and winter are 32˚C and 18˚Crespectively (FAO, 2006). The area has light, well drained, sandy soils of granite origin and resembles those found in most tobacco growing areas in Zimbabwe. The soils are very low in clay content and have low water holding capacity. They are slightly acidic with a pH of about 5.2. The seedbed site used in this study was a north facing slope as recommended (TRB Handbook, 2011), which is better exposed to the sun and usually more protected from the prevailing cold winds in winter. A water tank provided adequate, reliable water supply which was easily accessible for seedling watering. The site was fenced to keep out animals and unauthorised persons, the upper side was protected by a storm drain to divert water that could erode the site or contaminate it with nematodes and other pathogens.

3.2 Description of varieties used in the study

The varieties used for this trial were the standard variety namely KRK 26 which can adapt to most tobacco growing areas in Zimbabwe. Also three pre-released varieties namely T70, T 74 and T 76 which are believed to be high yielding varieties were also used. KRK 26 is a slow growing cultivar that does well even under relatively low moisture levels. The variety has average internodes with crinkly leaves. Yield potential is low to medium and the quality is soft, clean, mostly lemon type with some orange colour. It is a long season variety grown in high altitude, high rainfall and a warm-cool temperature crop. It is recommended on heavier soils, second year land and situations where angular and *Alternari a* is a problem and on land which is to be second year in the following season. Pre released varieties T70, T 74 and T 76 are all believed to be fast growing varieties doing well in medium to higher moisture levels. Yield potentials are generally higher for T 74 and T 76 but for T 70it is low to medium yielding since it was developed from KRK 26 differing only in resistance to tobacco mosaic virus. Varieties T 74 and T 76 are short to medium season varieties and the quality is soft, clean, orange type varieties with some lemon colour and longer internodes.

3.3 Experimental design and treatments

A Split-plot arrangement in a Randomised Complete Block Design (RCBD) with 4 replications was used. The main plot factor A was the variety and the levels were (KRK 26, T70, T 74 and T 76) and the sub plot factor B was the intra row spacing with four levels which were 46, 56, 66 and 76 centimetres (Table 3.1).

Table 3.1: Treatment combinations of plant spacing and tobacco varieties used

	Variety			
Intra row spacing	KRK 26	T70	T 74	T 76
46cm	T1	T5	T9	T13
56cm	T2	T6	T10	T14
66cm	T3	T7	T11	T15
76cm	T4	T8	T12	T16

3.3.2. Experimental Procedure

3.3.3 Nursery Management

Seedbed activities commenced in June 2013and the starting point was the clearing of seedbed site. This was followed by bed construction in the seedbed. A bed measuring 20 metres long and 1.05m wide was constructed. Two courses of 11.25cm farm bricks were used and were set in position without mortar. The bed was lined with a 250 micrometer gauge black plastic. The bed was filled with water to a depth of 10cm to flatten the plastic against the bottom and the sides of the pond to avoid wrinkles.Pine bark 100% composted was the medium used in the float tray system. Float trays were filled with the growth medium. This was followed by dibbling creating dibbles or holes in which the seeds were sown by hand using a dibbler. This was followed by sowing in the tray by hand. The trays were then floated in the ponds in the seedbed.

Kutsaga float bed fertiliser (4.5% N,:2.1 % P_2O_5:4.7 % K_20) was then applied at 25, 50 and 75mg N/L of water in the seedbed at 7, 14 and 35 days after sowing. Ammonium Nitrate (34.5 % N) at 100mg N/L of water was applied to the trays at 42 days after sowing. Water was refilled and replaced in ponds regularly to allow new air circulation so that oxygen levels would be replenished and proper root respiration promoted. This was also done to replenish the reduced water levels and avoid seedling wilting. Sporekill with the active ingredient (*Didecylmethylammonim chloride* 120g/L) was used to control algae at a rate of 0,3ml/L for one hectare seedbed. Ridomil gold with the active ingredient (*Mefenoxam*45.3%) was used as a preventive treatment, 35 days after sowing at the rate of 213 g/hectare bed against pythium root rot. Trimming of seedlings was done using a clipper to ensure uniformity of the seedlings and to enhance hardening before transplanting. Before transplanting seedlings were then hardened by depriving them of nutrients and water for 14 days. At the end of the hardening process, 48 hours before transplanting, a chemical called Baytan plus Triademenol 15% WP was applied with a dilution rate of 165g/100L of water and an application rate of 2litres per square metre to prevent sore shin disease caused by *RhizoctoniaSolani*.

3.3.2.2. Land preparation

Deep ploughing was done using a tractor to a depth of 40cm, immediately following the rains (April). Deep ploughing early allows organic matter to decompose. The land was then harrowed using a disc harrow to allow a fine tilth to be obtained of vegetation before actual planting was done. Agricultural lime ($CaCO_3$) was applied as a broadcast at 1000kg per hectare to correct soil Ph. Flat-topped ridges were constructed which allowed maximum penetration of early rains. The height of the ridges was about 20cm. The ridges consisted of fine mixed soil and hence provided maximum amount of soil nutrients in a small area. The soil was loose and friable allowing easy root penetration. Fumigation was done two weeks before planting to control soil borne pathogens especially nematodes. Ethylene dibromide was used as a pre-planting fumigant at an application rate of 125ml/100m ridge.

3.3.2.3. Planting of tobacco seedlings

Water planting with water was done 12 weeks after sowing. The size of the planting hole was 20cm and chlopyrifos 48 % EC was then applied at the rate of 50mls/25L of water in every planting hole. Chlopyrifos was applied at the base of the plant to prevent cutworms (*Agrotis sergetum*). Float seedlings were pulled after hardening when they were 8-12cm long and pencil thick. Planting stations were marked in each ridge with a hoe, 56cm apart. The distance between ridges was 120cm. Fertiliser application was done to the respective treatments, were applied in right in the planting holes following the standard fertiliser recommendations. Water was poured into each hole using a hose pipe at about 2 litres per planting station. Seedlings were then planted to a depth of 5cm. The process was repeated wherever gap filling was necessary.

3.3.2.4. Fertilization in the field

Basal fertilizer application was done using Compound C (6N:15P:12K) at two weeks after planting at a rate of 600kg per hectare. Double banding was done using a spade at least 10cm on both sides of the plant. Ammonium Nitrate (34.5 % N) was applied as top dressing fertiliser at a rate of 150kgs per hectare. Dolloping sticks were used to create a hole into the ground less than 5 cm below surface and 10 cm away from the plant before placing fertilizer in the hole. The first split application was done at 3 weeks after planting at the rate of 100kgs and at three weeks after topping at a rate of 50kgs per hectare.

3.3.2.5. Weeding

Land was kept weed-free especially during the first 4-5 weeks following planting since the crop cannot tolerate weeds. During the period from two weeks after planting manual weeding was done by means of hand hoeing. After the crop had established and seven weeks after planting, re-ridging was done to remove weeds that had re-grown in the furrow and on the sides of the ridge, re-ridging also helped to maintain the structure of the ridges so that proper drainage occurs since tobacco is tolerant to water logging. Weeds were removed early and crops were kept weed-free during their period of major growth.

3.3.2.6. Topping and Suckering of tobacco

Topping was done when ten percent of tobacco plants have reached the required leaf number of eighteen leaves and the top most leaf was 15cm in length. Suckercides N-Decanol was and pendimethalin were applied at the rate of 8 and 5mls respectively per every topped plant. The remaining un-topped plants were then topped 7 to 10 days later.

3.3.3. Data Collection

3.3.3.1. Stalk height

A metre rule was used to measure the plant height. Stalk height was obtained by measuring the distance from the ground level to the topped part of the plant. Ten representative plants in each plot were used as samples. Stalk height was taken at the fourth week after planting and biweekly thereafter until physiological maturity of the crop.

3.3.3.2. Leaf Geometric Mean

Leaf geometric mean of the tobacco plants were obtained by calculating the mean leaf length and mean leaf width per plot and then multiplying them altogether and finding the square root of the product as shown below:

$$\sqrt{MeanLXMeanW}$$

A metre rule was used to measure both the leaf length and leaf width. Measurements for Leaf length and leaf width was done at 11 weeks after planting. The crop that was assessed was tagged on the third leaf to allow more data to be collected as well as for consistence measurements. The middle row plot in a three row plot was the assessment row measuring 1.2mx 17m. Leaf dimensions of 10 plants within each assessment row were taken. The overall experimental plot was 220 metres by 16.8 metres giving a total plot size of 3696m$^{2.}$ The total area of assessment rows was 816m^2 since each assessment row was 16.8m and there were 48 assessment rows.

3.3.3.3. Grade Index

Leaf maturity was shown by a change in colour from green to yellow. Tobacco was reaped ripe to ensure maximum yield and desirable quality.1-2 leaves per plant per week was reaped to allow uniform curing and this assists in grading. This ensures that only tobacco of similar stalk positions is reaped. Uniform loading of the leaves into the ban was done to ensure adequate airflow, which is necessary for top-quality cures. The leaves were sorted according to type, colour, size, texture and blemish and then graded in terms of the reaping groups, quality, colour and defects (Flue-cured tobacco production field guide, 2011).

Table 3.2 Flue cured tobacco field guide on quality evaluation and reaping groups

Grading criteria	Quality classes	Colour classes	Defects
Lugs (L)	Fine (1)	Lemon (L)	Badly handled (Bhd)
Primings (P)	Good (2)	Orange (O)	Funked (Fd)
Leaf (L)	Fair (3)	Light mahogany (R)	Mouldy (Ld)
Scrap (A)	Low (4)	Dark mahogany (S)	Mixed (Md)
Short leaf (T)	Poor (5)	Green (G)	Stem rot (Sad)
		Pale lemon (E)	Split (Sd)

Thus the tobacco classification was according to the major leaf classification symbols used in Zimbabwe (Flue-cured tobacco production field guide, 2011).

The Grade index (%) was then calculated by the following formula according to Idrees and Khan (2001):

$$\text{Grade index} = \frac{\text{(Weight (kg) of cured upper grade leaves in a treatment)}}{\text{(Total weight (kg) of cured leaves in a treatment)}} \times 100\%$$

3.3.3.4. Yield

The saleable yield/ha for each treatment was obtained using the following formula according to Idrees and Khan (2001):

$$\text{Cured leaf yield/hectare} = \frac{\text{Total cured weight (kg)}}{\text{Net area harvested } (\text{m}^2)} \times 10000\text{m}^2$$

3.3.3.5. Nicotine content of cured tobacco leaves

Nicotine content of the cured leaves was determined by the method of nicotine in environmental tobacco smoke using mass spectrometry. Cured tobacco leaf samples were taken for each treatment in each block. Leaves were then cut into small pieces and pulverised into powder form. The dried powder (0.1 g) was extracted three times with about 5mls of methanol by sonication method for 30 minutes. It was then filtered and the filtrate was evaporated near to dryness by an evaporator. The extract was passed through the cleanup column, which was filled with cotton in the bottom. An activated silica gel (10 g) soaked with solvent was loaded into the cleanup column of about 5 cm, which was then topped with 1.5 cm of anhydrous sodium sulfate. Five milliliters of solvent were added to wash the sodium sulfate and the silica gel.

The extracts (1 ml of each sample) were then separately transferred into the column, and the vessel was rinsed twice with 2 ml loaded solvent, which was also added to the column. Sixty milliliters of loaded solvent were added to the column and allowed to flow through the column at a rate of 3–5 ml/min, and the eluent was collected. The collected eluent from the cleanup procedure was re-concentrated to 2 ml by using K-D concentrator. Finally the extract (2 ml) from leaves was filtered through a 0.45 lm Millex HA filter (Millipore, Molsheim, France) prior to GC–MS analysis. The methanol extract (1 ml) was diluted with 5 ml of methanol and the samples were filtered through 0.45 lm membrane filters (Molsheim, France) prior to GC–MS analysis. The GS-MS analysis produced values of nicotine concentration in leaf samples and it was expressed as a percentage of the dry leaf weight before analysis. Leaf quality: The amount of sugars in the leaves was also evaluated by the Analytical chemistry services division. Values for sugar and nicotine contents were compared to find if they match with the required ratio of 6:1 which is the desired sugar to nicotine ratio for a desired, chemically balanced high quality tobacco leaves.

3.3.4. Data analysis

Analysis of variance was done using Genstat 14th Edition on all measured data and the means were separated using the Duncan's Multiple Range Test at 5% level of significance.

CHAPTER FOUR

4.0 RESULTS

4.1 Effect of intra row spacing on stalk height of tobacco varieties

There was an interaction (P< 0.05) between the variety and the intra row spacing. Results of this study have shown that higher/taller stalk heights were observed at closer intra row spacings (46 and 56) centimetres and they were not significantly different for all the varieties. Stalk height decreased significantly for all the varieties as the intra row spacing widened (66 and 76) centimetres. However, for varieties KRK 26 and T 70 stalk heights were significantly higher than for varieties T 74 and T 76 at wider spacings (Fig 4.1) with no significant differences between the sets of varieties KRK 26 and T 70and varieties T 74 and T 76.

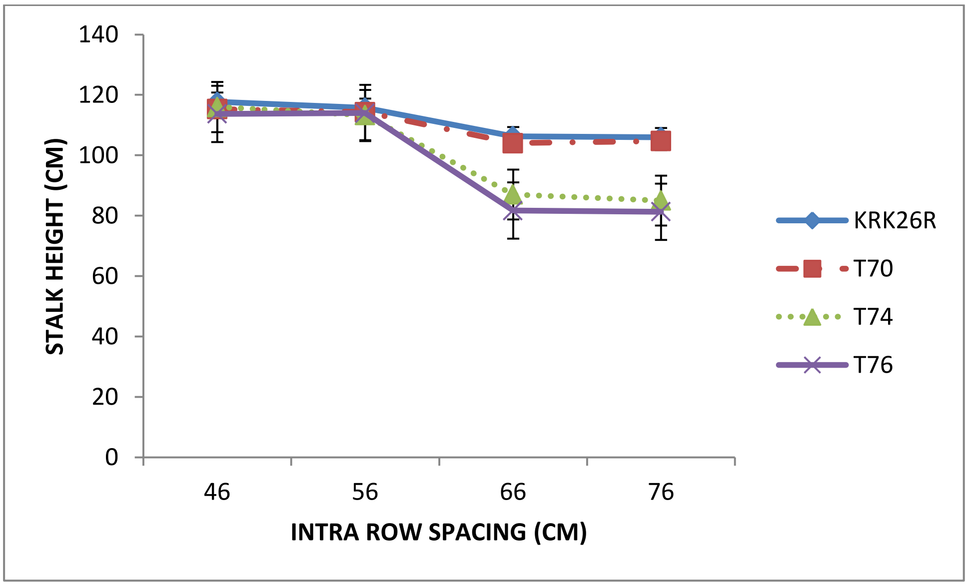

Fig 4.1 Effects of intra row spacing on stalk height of tobacco varieties

4.2 Effect of intra row spacing on leaf geometric mean of tobacco varieties

There was an interaction (P<0.05) between intra row spacing and variety on leaf geometric mean of tobacco varieties. At closer intra row spacings (46 and 56) centimetres varieties T70, T 74 and T 76 were similarly and significantly higher than variety KRK 26. At wider spacings (66 and 76) cm, varieties KRK 26 and T 70 were statistically similar and significantly lower than the varieties T 74 and T 76. Leaf geometric mean improved from closer spacings to wider spacings as shown in (Fig. 4.2).

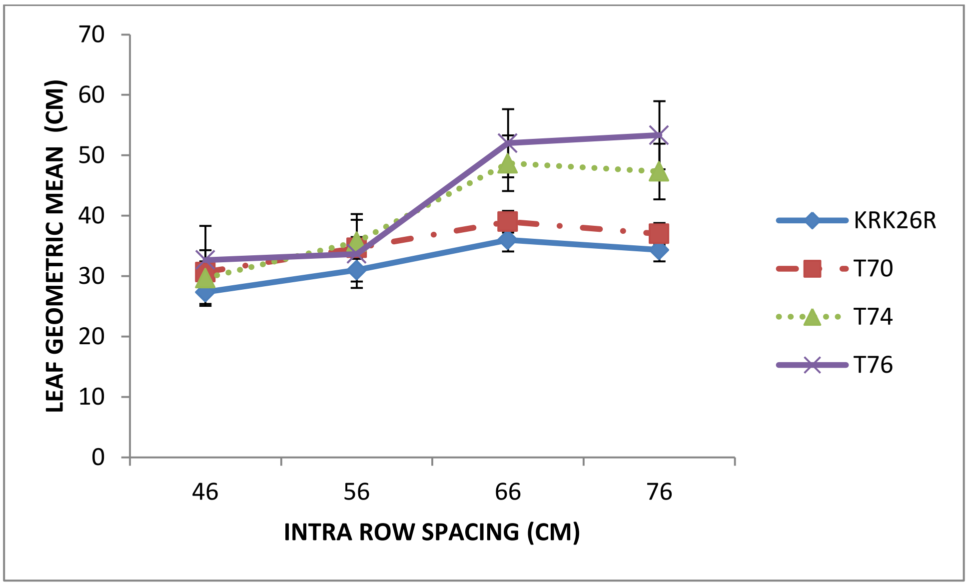

Fig 4.2Effects of intra row spacing on leaf geometric mean of tobacco varieties

4.3 Effect of intra row spacing on saleable yield of tobacco varieties

There was an interaction ($P<0.05$) between the intra row spacing and the variety on saleable yield of tobacco. At closer spacings (46 and 56) centimeters there were no statistical differences among all the varieties in terms of saleable yield. At wider intra row spacings (66 and 76) centimeters T 70 and KRK 26 produced the least saleable yield that was statistically lower than the saleable yield for varieties T 74 and T 76. Saleable yield improved as intra row spacing widened for all the varieties as shown in (Fig.4.3).

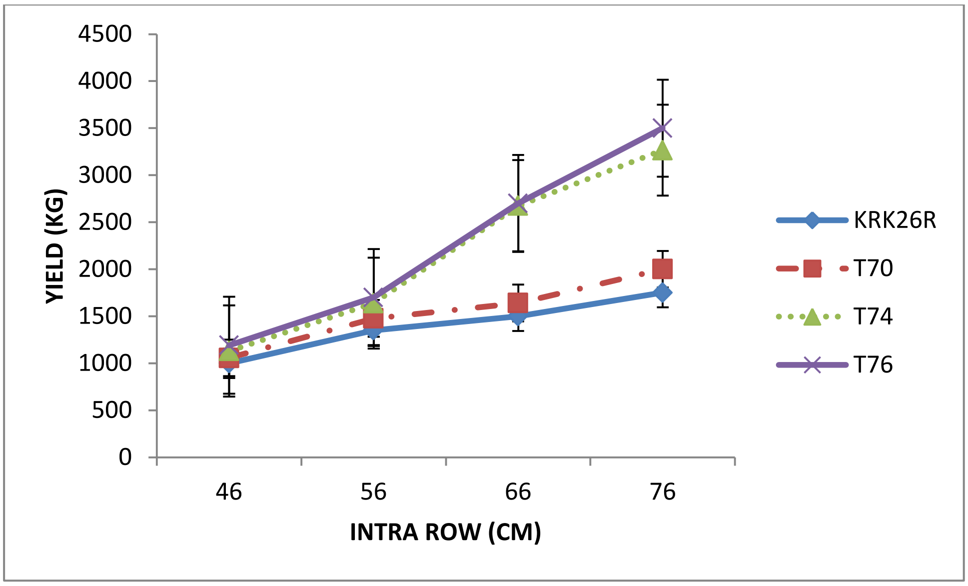

Fig 4.3 Effects of intra row spacing on saleable yield of tobacco varieties

4.4. Effect of intra row spacing grade index percent of tobacco varieties

There was an interaction ($P<0.05$) between the variety and the intra row spacing on grade indices of tobacco. At closer intra row spacings there were no statistical differences among all the varieties in terms of the percentage grade. At 66 centimeters T 70 and KRK 26 similarly and statistically low than varieties T 74 and T 76. Generally higher percentage grade for varieties T 74 and T 76 produced better quality in terms of percentage of better grades at wider spacings as shown in (Fig 4.4.)

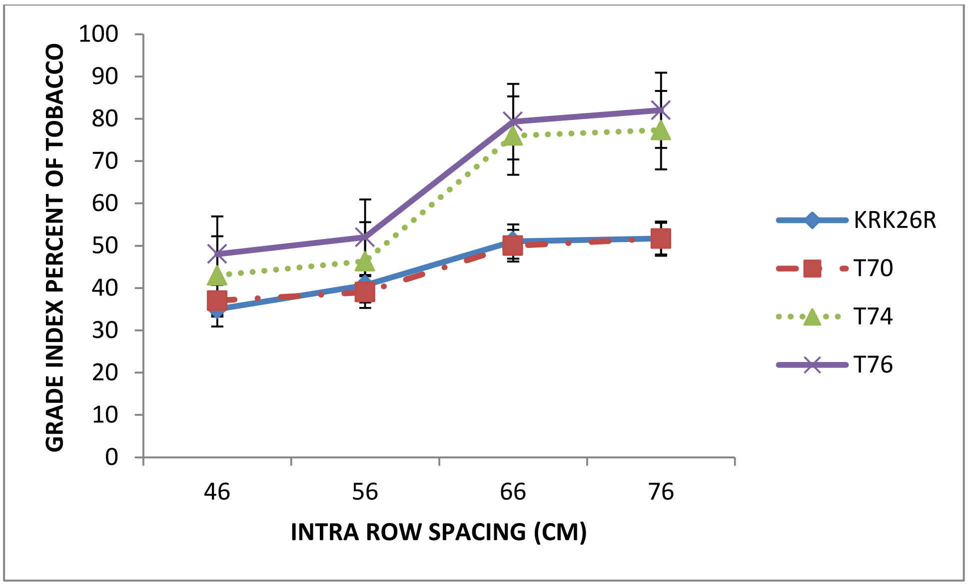

Fig 4.4 Effects of intra row spacing on grade index percent of tobacco varieties

4.5. Effect of intra row spacing and variety on nicotine content of tobacco varieties

There was an interaction (P<0.05) between the intra row spacing and the variety on nicotine content of tobacco. At closer spacing (46 and 56) centimetres varieties KRK 26 and T 74 were not statistically different, varieties T 70 and T 76 produced similarly and statistically higher levels of nicotine content than KRK 26 but were statistically similar to T 74. At wider spacings (66 and 76) centimetres KRK 26 had the least nicotine content levels. Varieties T70, T 74 and T 76 were similarly and statistically different from the variety KRK 26. Although T 74 had statistically lower nicotine content levels at closer spacings nicotine content sharply increased with wider spacing as shown in (Fig 4.5).

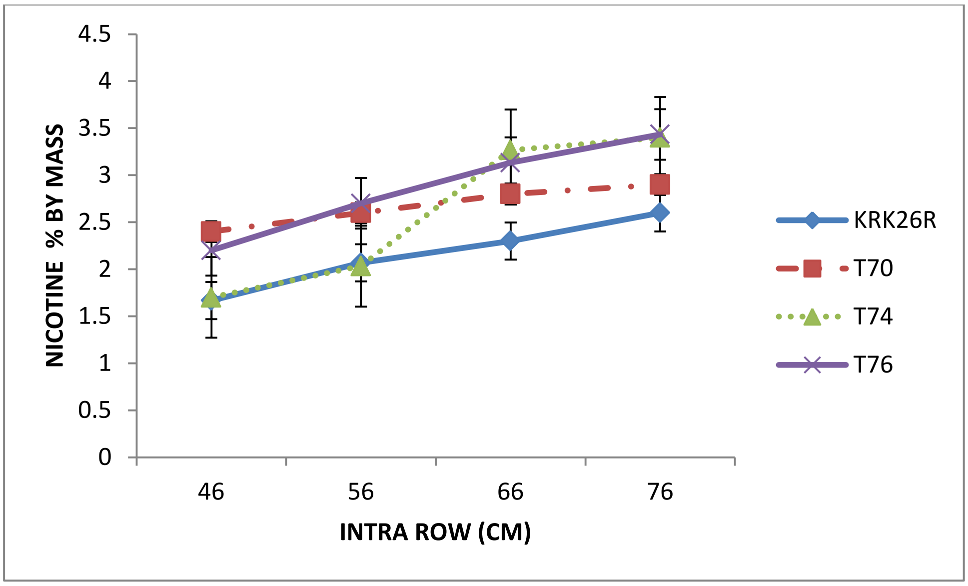

Fig 4.5 Effects of intra row spacing on nicotine content of tobacco varieties

4.6 Effects of intra row spacing on sugar content of tobacco varieties

There was an interaction (P<0.05) between the intra row spacing and sugar content of tobacco. At 46 centimetres KRK 26 and T 74 produced lower sugar content levels and it was significantly different from T 70 and T 76. As spacing increased to 56 cm, KRK 26, T 74 and T 76 have lower sugar levels and there were no statistical differences amongst these varieties, variety T 70 had significantly higher sugar content levels than the rest of the varieties. At 66 centimetres T 70 had the least sugar level though it was not significantly different from T 74 and T70. At an intra row spacing of 76 centimetres which is the widest spacing used in this study KRK 26 and T 70 produced lower amounts of sugars and KRK 26 was significantly different from T 74 and T 76 as shown in (Fig. 4.5).

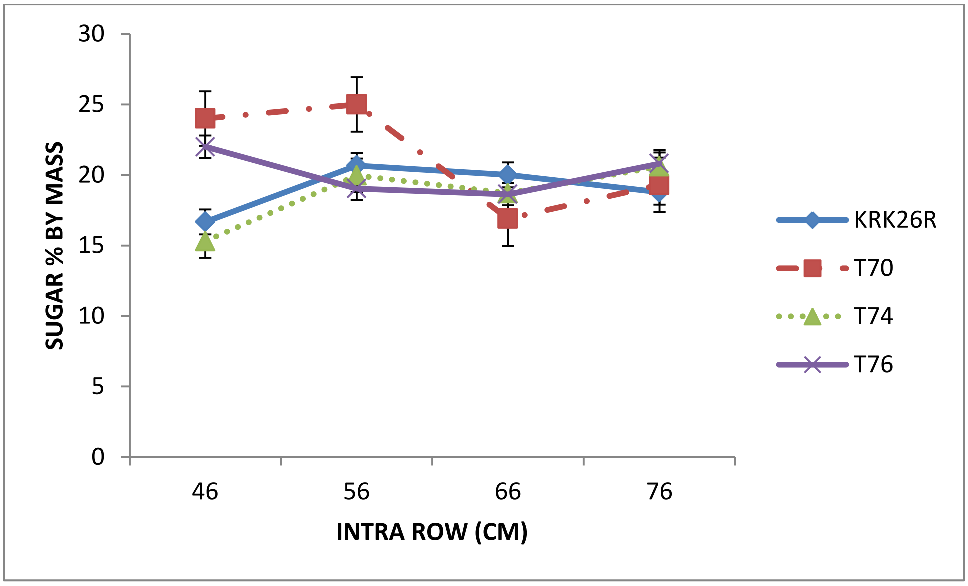

Fig 4.6 Effects of intra row spacing on sugar content of tobacco varieties

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effect of intra row spacing on stalk height of tobacco varieties

Results of this study showed that stalk heights were higher at closer intra row spacings and significantly decreased with wider intra row spacing. This might have been a response to mainly light as well as nutrient competition. In addition to that varietal influence may also have been another factor because KRK 26 and T 70 are related in terms of their genetic makeup in that T 70 was bred from KRK 26 and it only differs in its ability to resist tobacco mosaic virus. These two varieties are generally small statured to medium statured and the average stalk height of a normal plant stand is 100-110 cm (TRB, 2013). For varieties T 74 and T 76, the average stalk height of a normal plant stand ranges from 80-100 centimetres (TRB, 2013). However at closer intra row spacings all the varieties reached an average stalk height of between 116-120 centimetres which is more than the average stalk height of a normal plant stand for these varieties. The current plant intra row spacing for tobacco is 56 cm. Results of the study obtained show that the stalk heights obtained were probably due to a negative response to dense population of plants at closer intra row spacings because as the spacing widened, normal average stalk heights were observed for all the varieties used in this study. This may be because at wider intra row spacings optimum yielding plant populations in terms of availability of resources was available and therefore reducing resource competition and thus leading to attainment of normal stalk heights since normal vegetative growth might have occurred further showing that competition for growth resources is critical. This is in agreement with (Bukan, 2008) who pointed out that tobacco crop plants grown at closer intra row spacing will suffer severe resource competition to greater extents and they tend to produce taller stalks due to negative response to light and nutrient competition. This is because nutrients are required for vegetative growth and stalk height is one such important parameter of vegetative growth that is greatly affected by light competition.

5.2 Effect of intra row spacing and variety on leaf geometric mean of tobacco

At closer intra row spacings leaf geometric mean was low and it sharply increased as intra row spacing widened. Due to a higher density of plants per unit area due to closer intra row spacings (46 and 56) cm, competition of growth resources such as water, nutrients and light might have been increased such that vegetative growth might have inefficiently occurred and therefore resulting in limitations in the maximum growth potential/capacity of plants resulting in failure to reach maximum size and affecting growth parameters like leaf length and width. It is those parameters which are considered for leaf geometric mean assessments so if there is smaller leaf length and width it automatically translates to leaf geometric mean. Variety might have played a role in that it was observed that for KRK 26 and T 70 leaf geometric mean significantly improved as spacing widened. Leaf expansion surpassed the general expansion capacity usually obtained at the recommended current intra row spacing of 56 centimetres. This may be due to the fact that these varieties are generally small to medium statured and their maximum leaf expansion capacities in terms of geometric mean is usually between 25 to 40 (TRB, 2013) so competition may have occurred at closer intra row spacings but to a lesser extent when compared to varieties T 74 and T 76.

Competition for varieties T 74 and T 76 might have been more intense because of varietal morphology in that these varieties are gigantic statured though generally shorter in height. Their maximum leaf expansion capacities can reach up to 70 cm in terms of the leaf geometric mean as according to (Mudzengerere, 2013) which is more than double that of small statured varieties T 70 and KRK 26 though they are generally taller in height. This means that resource competition for the gigantic statured varieties may be higher than the small statured to medium statured varieties if same amounts of resources are availed to them. Furthermore, it may be concluded that closer intra row spacings tend to promote competition of resources though this can be amplified by varietal morphology. This agrees with the findings by Tso (1990) who mentioned that closer spacing of plants results in a reduction in leaf length and leaf width and therefore leaf geometric mean, crop stature (body), leaf thickness and leaf weight and these variations can depend on spatial arrangements and cultivar characteristics. In conclusion variation in responses to closer and wider intra row spacings may have been caused by varietal morphology and physiology in that the demand for water and nutrients as well as light may differ with varieties and this causes some varieties to be more affected than others if the same growth resources are available.

5.3 Effect of intra row spacing and variety on saleable yield of tobacco

Results of this study showed that saleable yield was lower for all the varieties at closer intra row spacings and greatly increased as the intra row spacing widened. It was observed that varieties T 70and KRK 26 behaved in a similar way most probably because they are genetically related. Varieties T 74 and T 76 also behaved in a similar way even if they are not related. Generally these two varieties are medium to high yielding varieties. Overally all the varieties produced more yield at wider intra row spacings than at closer intra row spacings. The general trend was observed that those varieties that produced higher leaf geometric mean resulted in more saleable yield than those that produced lower leaf geometric mean. In addition it was also observed that generally those varieties that had higher stalk heights resulted in lower yields than those with lower stalk heights. Tobacco quality and yield are mainly determined in the field and probably there was more intense resource competition in the field at closer spacings than at wider spacings. Competition for resources during field conditions tend to affect vegetative growth due to reduction in photosynthetic efficiency and therefore affecting important processes such as partitioning of assimilates and this in tobacco results in crops of taller stalk heights, thinner and paler leaves of lighter weight. Leaves from closer intra row spacings were generally of lighter weight as indicated by the mass reading during weighing and this might be the reason for may be reason for the lower mass of cured leaves and therefore saleable yield. This may also be attributed to the wider intra row spacings in that, due to minimum competition, efficient photosynthesis and therefore vegetative growth and assimilate partitioning were promoted causing higher accumulation of biomass. This in tobacco usually results in normal crop stands, producing plants with fully expanded leaves and higher weight which translates to cured leaf mass and thus saleable yield (Mazarura, 2013).

Varietal influence may also have occurred due to differences in morphology and physiology and thus causing differences in response to competition, resource use and efficiency in utilisation, affecting photosynthetic efficiency, growth and biomass accumulation and finally the cured leaf mass (saleable yield). These findings are in agreement with several other authors including (Kutjevo, 2005); (Masuka 2011); (Mudzengerere 2013); (TRB, 2013) who pointed out that saleable yield of the flue cured leaf may be higher for those leaves that are produced from wider intra row spacings than those from closer intra row spacings due to the fact that leaves from wider spaced fields are generally bigger in size than those from closer spaced fields. Kozumplik and Lamarre (1979) postulated that leaves from wider spaced tobacco plants generally produce more leaf weight than those from closer spacings; this is because they were raised from environments that have limited or lower resource competition and thereby allowing them to accumulate more assimilates and thus more weight.

5.4 Effect of intra row spacing and variety on percentage grade indices tobacco

Grade was generally low for closer intra row spacings and higher grade indices were obtained from wider spacings. Varieties KRK 26 and T 70 obtained similar and significantly lower grades at both closer and wider intra row spacings than varieties T 74 and T 76 which also produced similar grade indices at both closer and wider spacings. Results for grade indices may be attributed more to differences in varietal morphology because even at closer spacings the higher yielding varieties (T 74 and T 76) have better grades than the low to medium yielding varieties (KRK 26 and T70). This is because the higher yielding varieties already have a higher proportion of upper grade leaves than the low to medium yielding varieties and it is more important to note that it is these upper grade leaves that determine more of the tobacco grades than the lower primings, lugs and cutterers. However besides the influence of the varieties, intra row spacing also played a crucial row in that for all the varieties, tobacco grades improved significantly from closer intra row spacings to wider intra row spacings. This is consistent with the findings of Zhang and Zhang (2011) who indicated that leaf size is very important in determining grade index because smaller leaf sizes usually result in lower grades since leaf size is the first aspect to consider on cured leaf quality. The author pointed out that small leaf sizes are usually of lower quality while large leaf sizes usually result in higher quality if considering the issue of leaf size though other factors such as leaf colour and extent of damage as well as texture may are also important.

5.5 Effect of intra row spacing and variety on nicotine content of tobacco

Nicotine content was generally low across all the intra row spacings for variety KRK 26 R. At closer intra row spacings (46 and 56 centimetres) nicotine content levels were also low for variety T 74 though it is a high yielding variety however it sharply increased in nicotine content as spacing widened (66 and 76 cm). For varieties T 70 (low to medium yielding) and

T 76 nicotine content levels were generally higher even at closer intra row spacings though it also increased significantly as the spacing widened. Nicotine is an alkaloid and it is synthesised in the root tip and transported through the xylem vessels and then deposited in the leaves (Mudzengerere, 2013). The root tip is the source of nicotine while the leaf is the sink for nicotine. So due to closer intra row spacing competition might have occurred for soil water, light and nutrients and this affected the availability of nitrogen such that nicotine might have been produced in lower or inadequate amounts in the soil. In addition to that, competition tends to affect the vegetative development of the crops and therefore the crop may have smaller leaf sizes and since the leaves are the sinks for nicotine this may have a bearing on the balance between the sink to source relationship resulting in lower amounts being deposited in the leaves since the sinks may be limiting the source due to reduced surface area of deposition of nicotine (Yemmane, 2013). Furthermore, varieties may also differ in their nicotine formation and deposition abilities. This can be observed with such varieties as T 70, though it is a low to medium yielding variety it produced high nicotine levels across all the spacings and also variety T 74 produced lower nicotine levels at closer spacing only to sharply increasing at 66 and 76 centimetre spacings. Though these varieties generally improved with wider spacings, unexpected response observed at some intra row spacings may be attributed to varietal influence. The results of this study are similar to the findings of Rapper (2006) who found that closely spaced tobacco plants produced leaves of lower nicotine content levels compared to those in wider spacings due to competition for nitrogen which is a component of nicotine. The author also cited that some varieties have the capability to synthesise more nicotine regardless of nutrient competition due to their high nitrogen use efficiency.

5.6 Effect of intra row spacing and variety on sugar content of tobacco

Sugar content was initially higher at closer intra row spacings for varieties T 70 and T 76 and it decreased as the spacing widened. However, for varieties KRK 26 R and T 74 sugar content was initially low and it increased at 56 cm intra row spacing and remained generally low as the intra row spacing widened. Sugar levels tend to vary in accordance to the levels of nicotine in the leaves in that if there is low nicotine content more starch and sugars tend to accumulate in the leaves and if nicotine content is higher in the leaves usually the levels of sugars tend to go down. It is important to note that values for nicotine content and sugar levels were obtained in this study and therefore for quality testing it is a recommendation that chemical balance should be obtained to evaluate leaf quality, and so in this study since the values for nicotine and sugar levels were obtained it was possible to calculate the ratios and compare them to the desired ratio. However results of this study showed that nicotine to sugar ratios of up to 10:1 for higher yielding varieties at closer intra row spacings were noted and this is undesirable as the leaves are generally considered to be of poor quality. The general trend observed in this study, was that at closer spacings there were higher levels of sugars and the levels declined with wider intra row spacings. It has also been shown that variations in leaf sugar to nicotine levels can depend greatly on varieties nitrogen use efficiency (NUE) (Masuka, 2011). Varieties with high NUE usually produce desired levels of nicotine than those with low NUE and therefore accumulate more nicotine in the leaves thus reducing the ratios. Results of this study are in agreement with the findings by Raper and McCants (2006), who concluded that low or inadequate nitrogen causes plants to synthesise starch prematurely, and thus restricting nicotine production and favour starch accumulation (TRB, 2013).

CHAPTER 6

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

All varieties used in this study showed higher leaf expansion (leaf geometric mean), saleable yield, grade indices and desired nicotine to sugar ratios at wider intra row spacings (66 and 76) cm compared to closer intra row spacings. Stalk height was higher for all varieties at closer intra row spacings than at wider intra row spacing. At closer intra row spacings there were higher sugars to nicotine ratios which generally exceeded the desired ratio of 6:1 reaching as high as 10:1, more desirable characteristics in terms of yield and quality of tobacco were obtained at wider intra row spacings. Even the older variety KRK 26 produced better yield and quality attributes at wider intra row spacings compared to the closer intra row spacings inclusive of the current used spacing of 56 cm. Significant improvement in yield and quality attributes was observed particularly for the higher yielding varieties T 74 and T 76 at wider spacings, though improvement was noted for the medium to low yielding varieties at such spacings.

6.2 RECOMMENDATIONS

Farmers may resort to wider intra row spacings for optimum yield and quality of tobacco varieties used in this study. Future research should also establish the effects of supplementary nitrogen and irrigation on tobacco grown at closer intra row spacing since this has been shown to improve yield and quality by other researchers.Future research should also establish the effects of intra row spacing on weed suppression ability using the varieties used in this study as well as the cost benefit analysis of resorting to wider spacing. Future research must also establish nitrogen use efficiency capabilities for all the varieties used in this study as this can have a bearing on nicotine to sugar ratios and therefore affect leaf chemical composition and thus quality.Future research should be done to evaluate the effect of both inter and intra row spacing on growth yield and quality of varieties used in this study since the combined effects of these can alter the nature and extent of resource competition.

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APPENDICES

A 1: ANOVA for the effects of intra row spacing on stalk height of tobacco varieties at 11 WAP

Analysis of variance

Variate: STALK_HEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	10.50	5.25	0.07	
BLOCK.VARIETY stratum					
VARIETY	3	1649.83	549.94	7.14	0.021
Residual	6	462.17	77.03	1.40	
BLOCK.VARIETY.INTRA_ROW stratum					
INTRA_ROW	3	5055.17	1685.06	30.68	<.001
VARIETY.INTRA_ROW	9	1233.33	137.04	2.50	0.036
Residual	24	1318.00	54.92		
Total	47	9729.00			

A 2: ANOVA for the effects of intra row spacing on leaf expansion (leaf geometric mean) of tobacco varieties

Analysis of variance

Variate: LEAF_GEOMEAN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	3.88	1.94	0.15	
BLOCK.VARIETY stratum					
VARIETY	3	844.40	281.47	22.28	0.001
Residual	6	75.79	12.63	1.19	
BLOCK.VARIETY.INTRA_ROW stratum					
INTRA_ROW	3	1684.23	561.41	52.70	<.001
VARIETY.INTRA_ROW	9	470.35	52.26	4.91	<.001
Residual	24	255.67	10.65		
Total	47	3334.31			

A 3: ANOVA for the effects of intra row spacing on saleable yield of tobacco varieties

Analysis of variance

Variate: TOTAL_MASS_AT_UNTYING

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	81314.	40657.	3.93	

BLOCK.VARIETY stratum					
VARIETY	3	1353466.	451155.	43.64	<.001
Residual	6	62033.	10339.	0.53	
BLOCK.VARIETY.INTRA_ROW stratum					
INTRA_ROW	3	1215672.	405224.	20.91	<.001
VARIETY.INTRA_ROW	9	1645163.	182796.	9.43	<.001
Residual	24	465044.	19377.		
Total	47	4822692.			

A 4: ANOVA for the effects of intra row spacing on grade index of tobacco varieties

Analysis of variance

Variate: %_GRADE

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	93.88	46.94	0.76	
BLOCK.VARIETY stratum					
VARIETY	3	4237.83	1412.61	22.89	0.001
Residual	6	370.29	61.72	2.31	
BLOCK.VARIETY.INTRA_ROW stratum					
INTRA_ROW	3	6040.17	2013.39	75.29	<.001
VARIETY.INTRA_ROW	9	1007.00	111.89	4.18	0.002
Residual	24	641.83	26.74		
Total	47	12391.00			

A 5: ANOVA for the effects of intra row spacing on sugar content of tobacco varieties

Analysis of variance

Variate: SUGARS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	4.618	2.309	0.46	
BLOCK.VARIETY stratum					
VARIETY	3	51.471	17.157	3.44	0.092
Residual	6	29.910	4.985	1.07	
BLOCK.VARIETY.INTRA_ROW stratum					
INTRA_ROW	3	42.067	14.022	3.02	0.049
VARIETY.INTRA_ROW	9	191.221	21.247	4.58	0.001
Residual	24	111.452	4.644		

Total 47 430.739

A 6: ANOVA for the effects of intra row spacing on nicotine content of tobacco varieties

Analysis of variance

Variate: NICOTINE

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	0.003750	0.001875	0.13	
BLOCK.VARIETY stratum					
VARIETY	3	3.231667	1.077222	76.41	<.001
Residual	6	0.084583	0.014097	2.57	
BLOCK.VARIETY.INTRA_ROW stratum					
INTRA_ROW	3	8.871667	2.957222	539.04	<.001
VARIETY.INTRA_ROW	9	2.206667	0.245185	44.69	<.001
Residual	24	0.131667	0.005486		
Total	47	14.530000			