# TOBACCO RESEARCH INSTITUTE OF TANZANIA (TORITA)

# EVALUATION OF NEWLY INTRODUCED TOP DRESSING FERTILIZERS ON PRODUCTIVITY AND QUALITY OF FLUE-CURED TOBACCO

**BY**

**TORITA MANAGEMENT**

**Sponsored by YARA Fertilizer Tanzania**

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## ABSTRACT

Tobacco productivity in both yield and quality are highly determined by essential nutrient elements which are largely obtained from basal and top dressing using synthetic fertilizers. In order to evaluate the effect of different application rates of top dressing fertilizers of YaraLiva Nitrabor, YaraBela Sulfan and YaraMila on quantity and quality of flue cured tobacco, field experiments were performed at Tobacco Research Institute of Tanzania (TORITA) during the 2013/14 and 2014/15 cropping seasons, followed by on-farm experiment during the 2017/018 cropping season in diverse districts of Kahama and Chunya. Six different top dressing fertilizers (YaraLiva Nitrabor 66.668 kg/ha, YaraLiva Nitrabor 125 kg/ha, YaraBela Sulfan 55 kg/ha plus YaraLiva Nitrabor 83.335 kg/ha, YaraBela Sulfan 125 kg/ha, YaraMila tobacco NPK 10:18:24 310 kg/ha) and the control treatment CAN 27% 125 kg/ha were evaluated. The measured variables in tobacco were the leaf length and width, barn dry weight, percentage of nicotine, nitrogen, phosphorus, potassium, sulphur and boron concentrations on barn dry leaves, average grade index and gross margin analysis. Results revealed that the highest dry leaf yield with respect to top dressed fertilizers were recorded from YaraBela Sulfan 125 kg/ha being with weights of 2049.55,1904.86, 2055.00 kg/ha during the 2013/14, 2014/15 and 2017/018 cropping seasons, respectively. Treatment CAN 27% 125 kg/ha resulted into the lowest weights of 1824.18, 1720.37 and 1822.12 kg/ha during the 2013/14, 2014/15 and 2017/018 cropping seasons, respectively. Combination of YaraBela Sulfan 55 kg/ha and YaraLiva Nitrabor 83.34 kg/ha resulted into tobacco with relatively higher quality. Economic analysis revealed that the higher gross margin was attained with basal application of NPK 10:18:24 at 500 kg/ha was top dressed with a combination of YaraBela Sulfan 55 kg/ha and YaraLiva Nitrabor 83.34 kg/ha. The lowest gross margin was obtained when basal application of NPK 10:18:24 at 500 kg/ha was top dressed with NPK 10:18:24 at 310 kg/ha. YaraBela Sulfan (CAN 24% + 6% S) at a rate of 125kg/ha performed better than CAN 27% at 125 kg/ha in terms of quantity and quality of tobacco productivity. Therefore, it was revealed to be economically viable option to use CAN 24% + 6% S in top dressing flue-cured tobacco instead of using the fertilizer CAN 27%.

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**Key words:** Derived benefits; cropping practices; nicotine; plant nutrition; tobacco; trade-offs; YARA products; Tanzania.

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## 1.0 INTRODUCTION

Tobacco is a commercial crop, which requires well balanced supply of essential nutrient elements (FAO, 1984: Campbell, 2000). According to FAO (1984), an element qualifies to be essential if its deficiency makes impossible for the plant to complete the vegetative or reproductive stage of its life. Deficiency symptoms of an essential element can be corrected only by supplying the same nutrient element. The nutrient element should be directly involved in the nutrition of the plant (Campbell, 2000).

Essential nutrient elements supplied by the soil or feeding solutions are categorized into macronutrients and micronutrients. The macronutrients are nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulphur (S), which are required in relatively large quantities. On the other hand, the micronutrients are iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), molybdenum (Mo), and chlorine (Cl). Micronutrients are required in relatively small quantities. Most of the essential elements are supplied through application of synthetic fertilizers. In tobacco production, fertilizers are applied in order to improve both quantity and quality (David *et al.*, 2008). The functions of each nutrient element in a crop should be known before making decisions on what, when and how much to apply to optimize crop productivity.

## 1.1. NITROGEN

Flue-cured tobacco is very demanding in its N requirement. Mahdav and Gholizadeh (2008) reported that increasing N levels increased the length and width of leaves, green leaf yield and cured leaf yield, nicotine and total nitrogen. Available N is needed to sustain full growth until flowering. Marchetti *et al.* (2006) conducted an experiment on N fertilizer with the aim of verifying the influence of N rates on flue-cured tobacco yields. Five N rates (0, 20, 40, 60, and 80 kg N $ha^{-1}$) were tested on tobacco variety K326 with no application of P fertilizer and K was applied at a rate of 250 kg $ha^{-1}$. Their results indicated that the mean yield of cured leaves was 4105 kg $ha^{-1}$ and 3740 kg $ha^{-1}$, in 1998, and 1999, respectively and N rate of 80 kg $ha^{-1}$ gave cured-leaf yield of 4105 kg $ha^{-1}$ compared with the unfertilized control. The mean total N concentration in cured leaves was 29.2 g N $kg^{-1}$ in 1998 and to 22.1 g N $kg^{-1}$ in 1999.

A study conducted by Xiao-Tang *et al*. (2008) revealed that N supply is the most important factor affecting yield and quality of flue-cured tobacco. According to Xiao-Tang *et al*. (2008), the order of soil N contribution to N build-up in different parts of leaves was: upper leaves > middle leaves > bottom leaves. Thus, soil N mineralization at late growth stages was an important factor affecting N accumulation and, consequently, the nicotine content in the upper leaves.

## 1.2. PHOSPHORUS

Phosphorus is another important primary macronutrient after N and K, which is involved in energy and growth regulation and stimulates young root development (Hodges, 2012). It is essential in several bio-chemical reactions that control photosynthesis, respiration, and cell division. According to Hodges (2012), P improves water use efficiency and uniformity of crop maturity and quality. Uptake of P occurs primarily in the form of $HPO_4^{2-}$ and $H_2PO_4^-$ (orthophosphate) forms in acid soils and $PO_4^{3-}$ in alkaline soils. The concentration of P is higher in young leaves than in old leaves due to its high mobility (Marschner, 1990). Tucker (1993) reported that available P in tobacco cultivated soils increased to 207 kg $ha^{-1}$ due to continuously application of high P fertilizer grades as 3-9-9, 4-8-12 and 6-12-18. Similar author also reported that flue-cured tobacco yielding 3,363 kg $ha^{-1}$ removed only 11.31 kg of $P_2O_5$ $ha^{-1}$. The long-term application of P in excess of crop removal resulted in significant build-up of residual P reserves in tobacco soils.

## 1.3. POTASSIUM

Potassium is also an important primary macronutrient required by plants in approximately the same or slightly larger amounts as N. Uptake of K occurs in the form of $K^+$ and it is supplied as an oxide $K_2O$. Most functions of K in plant are indirect identified in that K is necessary for other chemical reactions to operate properly (Hodges, 2012). Potassium forms no organic compounds within a plant but remains in the ionic ($K^+$) form. Plant uses K in photosynthesis, carbohydrate transport, water regulation, and in protein synthesis (Marschner, 1990). The benefits of proper K nutrition include improved disease resistance, vigorous vegetative growth, and increased drought tolerance. Potassium improves stalk quality and reduces plant lodging, helps in opening and closure of leaf pores (stomata) more efficiently to control water loss during drought. In addition, K promotes rapidly and efficient conversion of N into protein (Litchfield, 2012).

Gholizadeh *et al*. (2012) reported that the highest dry leaf yield was 4501 kg/ha from fields treated with 69 kg nitrogen/ha. On the other hand, the highest dry leaf yield was 4238 kg/ha from fields where application was 225 kg potassium/ha. Brar *et al.* (2011) indicated that balanced fertilizer N and K application is an urgent need to achieve higher nutrients use efficiency (NUE). According to Brar *et al.* (2011), a gain of 20% in NUE can easily be achieved via balanced fertilization with K. A positive relationship between N and K exists for the uptake and utilization of N by plants to form protein and amino acids which ultimately affect the quality and yield of crops.

## 1.4. CALCIUM

Calcium is also an essential secondary macronutrient element; others being S and Mg. According to Litchfield (2012), Ca is involved in cell wall formation, translocation of sugars, root hair formation (feeder roots), and neutralization of poisons produced in the plant. Calcium encourages fruit and seed production, and it improves general plant vigour and stiffness of straw. Hodges (2012) reported that Ca as a structural component of plant cell walls is mostly abundant in leaves. It is also involved in cell growth both at the plant terminal and at the root tips, and apparently enhances uptake of nitrate-N. Calcium is not translocated within the plant; so an adequate supply throughout the season is important for sustained terminal and root growth (AESL, 2004).

Lo´pez-Lefebre *et al.* (2001) analysed the dynamics of the nutritional state and biomass production of tobacco plants. Their results showed that Ca accumulated progressively with increasing application of the same element. There was a slight rise in the concentration of organic N but hardly any change in the concentrations of K and Na. In contrast, increasing Ca application caused a decline in P and Mg concentrations. The concentrations of micronutrients Fe, Mn, Zn, Cl, and B were positively influenced by Ca application but Cu concentration declined significantly. A significant synergistic relationship was found between Ca and B.

Tobacco yield and quality are highly determined by the amounts of essential nutrient elements. Therefore, this study executed in order to evaluate the effect of different rates of top dressing fertilizers on tobacco yield and quality. The study is important in raising awareness to the farmers what type and rate of fertilizer should be applied and at what stage of plant growth in order to produce large tobacco on with high quality.

## 1.5. GENERAL OBJECTIVE

The overall objective of this study is to improve productivity and quality of the flue cured tobacco in Tanzania through application of different top dressing fertilizers to supplement nutrients requirements.

## 1.6. SPECIFIC OBJECTIVES

The specific objectives of this study were to:

1. Evaluate the effect of top dressing YaraLiva Nitrabor and YaraBela Sulfan in tobacco yield and quality

2. Assess the economic benefits and/or trade-offs derived from the use of YaraLiva Nitrabor and YaraBela Sulfan in tobacco production

## 2.0 MATERIALS AND METHODS

### 2.1 LOCATION

On-station experiment was carried out at Tobacco Research Institute of Tanzania (TORITA) which is located in Tabora Municipality along Urambo district road. The on-station installation of experimentation was done in the years 2013/14 and 2014/15 and later on the on-farm experiment was installed during the 2017/2018 cropping season due to lack of funds in the year 2016/2017.

### 2.2 RESEARCH DESIGN AND DATA COLLECTION

#### 2.2.1 Design

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Plants spacing was 120 cm ridge to ridge and 50 cm plant to plant with the plot size of 3.6 m x 17 m. The variety used was K326. Composite soil samples were taken at 0 – 20 cm depth from 18 replicate plots. The treatments involved were as shown in Table 1.

**Table 1: Treatments summary and nutrients applied in kg/ha**

| S/N | Treatment name | N | P | K | Mg | Ca | S | B |
|---|---|---|---|---|---|---|---|---|
| | | | | | (kg/ha) | | | |
| 1 | CAN 27% 7.5 g/plant | 83.7 | 90 | 120 | 2.5 | 15 | 35 | 0.5 |
| 2 | YaraLiva nitrabor 4 g/plant | 59.62 | 90 | 120 | 2.5 | 47 | 35 | 0.88 |
| 3 | YaraLiva nitrabor 7.5 g/plant | 69.25 | 90 | 120 | 2.5 | 47 | 35 | 0.88 |
| 4 | YaraBela Sulfan 3.3 g/plant plus YaraLiva nitrabor 5 g/plant | 74.9 | 90 | 120 | 2.5 | 21.3 | 38.1 | 0.75 |
| 5 | YaraMila tobacco 18.6 g/plant | 81 | 145.8 | 194.4 | 4.05 | 24.3 | 56.7 | 0.81 |
| 6 | YaraBela Sulfan 7.5 g/plant | 80 | 90 | 120 | 2.5 | 15 | 42.5 | 0.5 |

*NB: Basal application was NPK 10:18:24, 30 g/plant.*

Quartering technique was employed to get one kg of composite soil sample. Soil samples were sent to Sokoine University of Agriculture (SUA) for routine laboratory analysis. The analysis involved, total N, available P, exchangeable bases (K, Ca, Mg except Na), extractable S, extractable micronutrients (Mn, Fe, B, Zn, Cu except Mo and Cl) and cation exchange capacity (CEC), and soil reaction (pH). Results are presented in Table 2.

**Table 2: Soil nutrients results for Tumbi trial sites**

| Item tested | Unit | Results | Guide line | Interpretation | Comment |
|---|---|---|---|---|---|
| Total N | Mg/kg | 191 | 1000 | Very low | Treatment considered |
| P | ppm | 31 | 26 | Normal | Adequate level |
| K | ppm | 100 | 241 | Low | Treatment considered |
| Ca | ppm | 276 | 1600 | Very low | Treatment considered |
| S | ppm | 7 | 10 | Low | Treatment considered |
| Mg | ppm | 53 | 120 | Very low | Treatment considered |
| Mn | ppm | 167.77 | 15 | High | - |
| Fe | ppm | 251 | 200 | Normal | Adequate |
| C.E.C | meq/100g | 2.1 | 0 | High | High |
| B | ppm | 0.82 | 0.5 | Normal | Adequate level |
| Cu | ppm | 1.2 | 2.1 | Low | Treatment considered |
| Zn | ppm | 1.8 | 2.5 | Low | Treatment considered |
| pH | | 5.9 | 6.5 | low | Treatment considered |
| Lime required | | 0.0 | - | - | - |

**Table 3: Soil nutrients results for Kahama and Chunya trial sites**

| Kahama site | Units | Results | Interpretetion | Chunya site results | Interpretation | Guide line | Comment |
|---|---|---|---|---|---|---|---|
| N(Total) | Mg/kg | 191.6 | Very low | 191.9 | Very low | 1000 | Treatment considered |
| P | ppm | 30.9 | Normal | 29.9 | Normal | 26 | Adequate level |
| K | ppm | 98.99 | Low | 99.99 | Low | 241 | Treatment considered |
| Ca | ppm | 276.7 | Very low | 275.90 | Very low | 1600 | Treatment considered |
| S | ppm | 7.6 | Low | 7.8 | Low | 10 | Treatment considered |
| Mg | ppm | 53.6 | Very low | 53.8 | Very low | 120 | Treatment considered |
| Mn | ppm | 168.57 | High | 168.59 | High | 15 | - |
| Fe | ppm | 251.1 | Normal | 251.5 | Normal | 200 | Adequate |
| C.E.C | meq/100g | 2.0 | High | 2.0 | High | 0 | High |
| B | ppm | 0.85 | Normal | 0.89 | Normal | 0.5 | Adequate level |
| Cu | ppm | 1.4 | Low | 1.6 | Low | 2.1 | Treatment considered |
| Zn | ppm | 1.7 | Low | 1.55 | Low | 2.5 | Treatment considered |
| pH | _ | 5.95 | low | 5.99 | low | 6.5 | Treatment considered |
| Lime required | | 0.0 | | 0.0 | | - | |

### 2.2.2 Data collection

Dry tobacco leaf samples of middle leaves were taken to the laboratory for analysis of nitrogen, phosphorus, potassium, sulphur, and nicotine. Other data collected and analyzed were the barn dry weight yield, leaf size, grade index and gross margin. For gross margin analysis the empirical model use was:

$$GM = TR - TC$$

Where; GM= Gross margin; TR= Total revenue obtained; TC= Total cost incurred; TR= $P_y y$; TC=$\sum P_{xi} x_i$; $P_{y=}$ Price of output; $P_x$= Price of the $i^{th}$ input ($/Unit); $X_i$=Quantity of $i^{th}$ input; (Unit/ha) used in producing Y.

## 3.0 RESULTS AND DISCUSSION

### 3.1 LEAF LENGTH AND WIDTH

In tobacco marketing, leaf length is an important grade attribute. Long leaves which come from properly fertilized and well cured plants fulfil the desirable qualities which acquire high grades. In Tanzania tobacco grades are based on leaf length, leaf position on a stalk, colour (orange, lemon, brown) and leaf entirety. In this trial, leaf length and width were measured and presented in Table 3 for the Tumbi site and Table 4 for the Kahama and Chunya sites. Interpretations made for the results generated during the 2013/2014 and 2014/2015 cropping seasons are from Tumbi site whereas those during the 2017/2018 are for Kahama and Chunya sites.

#### 3.1.1 TOP LEAVES

The highest average value of leaf length for top leaves was 49.25 cm during the 2013/14 cropping season in application of YaraLiva Nitrabor 125 kg/ha followed by 47.65 cm at YaraBela Sulfan 125 kg/ha). The shortest leaves were 45.19 cm in average from application of NPK 10:18:24 310 kg/ha. There was no significant ($P < 0.05$) difference among all treatments. During the 2014/15 cropping season the highest leaf length was 50.69 cm in top leaves at application of YaraMila tobacco 310 kg/ha followed by 50.35 cm in Yara Bela Sulfan 125 kg/ha. The shortest leaves were 47.70 cm long in CAN 27% 125 kg/ha although these differences did not differ significantly ($P < 0.05$).

During the 2013/14 cropping season the highest leaf width for the top leaves was 18.39 cm in YaraBela Sulfan 125 kg/ha followed by 17.22 cm in CAN 27% 7.5 g/plant. The lowest width was 15.90 cm. There were no significant ($P > 0.05$) differences among all treatments. During the 2014/15 cropping season the highest leaf width for top leaves was 20.27 cm in YaraMila tobacco 310 kg/ha followed by 19.21 cm in YaraBela Sulfan 125 kg/ha. The lowest width was 17.51cm in CAN 27% 7.5 g/plant with no significance ($P > 0.05$) differences among all treatments.

### 3.1.2 MIDDLE LEAVES

The highest leaf length during the 2013/14 season for middle leaves was 52.85 cm in YaraBela Sulfan 3.3 g/plant plus YaraLiva nitrabor 5 g/plant followed by 51.56 cm in CAN 27% 7.5 g/plant. The shortest leaves were 48.32 cm in YaraLiva nitrabor 7.5 g/plant. There were no significance (*P*> 0.05) differences among all treatments. During the 2014/15 season, the highest leaf length was 49.48 cm in YaraMila tobacco 18.6 g/plant followed by 48.17 cm in YaraBela Sulfan 7.5 g/plant. The shortest leaves measured 44.84 cm in CAN 27% 7.5 g/plant. There were no significance (*P*> 0.05) differences among all treatments.

The highest leaf width during the 2013/14 season for the middle leaves was 26.30 cm inYaraBela Sulfan 3.3 g/plant plus YaraLiva nitrabor 5 g/plant followed by 25.66 cm in YaraMila tobacco 18.6 g/plant. The lowest leaf width was 24.26 cm in YaraLiva nitrobor 7.5 g/plant. There were no significance (*P*> 0.05) differences among all treatments. During the 2014/15 season, the highest leaf width for the middle leaves was 20.97 cm in YaraMila tobacco 18.6 g/plant followed by 20.18 cm in YaraBela Sulfan 7.5 g/plant. The lowest leaf width measured was 18.28 cm in CAN 27% 7.5 g/plant. There were no significance (*P*> 0.05) differences among all treatments.

### 3.1.3 BOTTOM LEAVES

During the 2013/14 cropping season, the highest leaf length for bottom leaves was 41 cm in YaraLiva nitrabor 4 g/plant followed by 36.26 cm in YaraBela Sulfan 7.5 g/plant. The shortes leaves measured 32.85 cm in YaraBela Sulfan 3.3 g/plant plus YaraLiva nitrobor 5 g/plant. Treatment YaraLiva nitrobor 4 g/plant differed significantly (*P*< 0.05) from the rest of the treatments. During the 2014/15 season the highest leaf length for bottom leaves was 33.11 cm in YaraMila tobacco 18.6 g/plant followed by 32.06 cm in YaraBela Sulfan 7.5 g/plant. The shortest leaves was 29.06 cm in CAN 27% 7.5 g/plant. There were no significance (*P*> 0.05) differences among all treatments.

During the 2013/14 season, the highest leaf width for the bottom leaves was 19.84 cm in YaraLiva nitrobor 4 g/plant followed 18.40 cm in YaraMila tobacco 18.6 g/plant. The smallest width measured in the bottom leaves was 17.15 cm in YaraBela Sulfan 3.3 g/plant plus YaraLiva nitrobor 5 g/plant. We found that treatment YaraLiva nitrabor 4 g/plant differed significantly (*P*< 0.05) from treatment YaraBela Sulfan 3.3 g/plant plus YaraLiva nitrobor 5 g/plant.

During the 2014/15 cropping season, treatments YaraBela Sulfan 3.3 g/plant plus YaraLiva nitrabor 5 g/plant and YaraBela Sulfan 7.5 g/plant resulted into the highest leaf width of 17.77

cm followed by 17.61 cm in YaraMila tobacco 18.6 g/plant. The smallest leaf width was 15.29 cm in CAN 27% 7.5 g/plant. There were no significance (*P*> 0.05) differences among all treatments. For the on-farm assessment, the highest leaf length for the bottom leaves was from treatment YaraLiva nitrabor 66.7 kg/ha followed by leaves of plants treated with YaraBela Sulfan 125.0 kg/ha.

### 3.1.4 TOP LEAVES

The highest leaf length for the top leaves during the 2017/018 cropping season was 52.99 cm in YaraBela Sulfan125 kg/ha followed by 51.29 cm in treatment YaraMila tobacco 310.0062 kg/ha. The shortest leaf length for the top leaves 48.68 cm in treatment Yara-Liva nitrabor 125 kg/ha. There were no significance (*P*> 0.05) differences among all treatments.

### 3.1.5 MIDDLE LEAVES

The highest leaf length during the 2017/018 season for the middle leaves was 51.88 cm intreatment YaraMila tobacco 18.6 g/plant followed by 49.99 cm in treatment YaraBela Sulfan 125 kg/ha. The shortest leaves measured 46.64 cm in treatment CAN 27% 125 kg/ha. There were no significance (*P*> 0.05) differences among all treatments.

### 3.1.6 BOTTOM LEAVES

During the 2017/018 cropping season the highest leaf length for the bottom leaves was 33.00 cm in treatment YaraBela Sulfan 125 kg/ha followed by 31.34 cm in treatment YaraMila tobacco 18.6 g/plant. The shortest leaves measured 28.00 cm in treatment CAN 27% 125 kg/ha. There were no significance (*P*> 0.05) differences among all treatments.

However, the results showed that leaves from plots treated with YaraBela Sulfan 125.0025 kg/ha resulted into the longest leaves at the middle and at the top of the tobacco plant. Leaf length and width are highly influenced by balanced application of essential nutrient elements such as N, P, K plus other elements like S, Ca, B, etc. These findings concur with those of Mahdav and Gholizadeh (2008) who reported that increasing nitrogen levels in soils also increased length and width of leaves, green leaf yield and cured leaf yield, nicotine and total nitrogen.

**Table 4: Effect of different rates of top dressing fertilizers on bottom, middle and top leaves, Tumbi site**

| Tr. no | Treatment name | 2013/14 Results | | | | | | 2014/15 Results | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Bottom leaf | | Middle leaf | | Top leaf | | Bottom leaf | | Middle leaf | | Top leaf | |
| | | Length (cm) | Width (cm) | Length (cm) | Width (cm) | Length (cm) | Width (cm) | Length (cm) | Width (cm) | Length (cm) | Width (cm) | Length (cm) | Width (cm) |
| 1 | CAN 27% 125 kg/ha | 35.16 b | 17.69 ab | 51.56 | 24.88 | 47.65 | 17.22 | 29.06 | 15.29 | 44.84 | 18.28 | 47.7 | 17.51 |
| 2 | YaraLiva nitrabor 66.668 kg/ha | 41.00 a | 19.84 a | 50.15 | 25.43 | 45.84 | 15.96 | 29.39 | 15.5 | 47.55 | 19.28 | 48.33 | 18.26 |
| 3 | YaraLiva nitrabor 125 kg/ha | 35.76 b | 17.76 ab | 48.32 | 24.26 | 49.76 | 17.03 | 31.01 | 16.19 | 47.88 | 19.72 | 48.68 | 18.43 |
| 4 | YaraBela Sulfan 55 kg/ha plus YaraLiva nitrabor 83.335 kg/ha | 32.85 b | 17.15 b | 52.85 | 26.3 | 47.93 | 16.41 | 31.54 | 17.77 | 48.04 | 19.83 | 49.54 | 18.68 |
| 5 | YaraMila tobacco 310.0062 kg/ha | 35.98 b | 18.40 ab | 50.8 | 25.66 | 45.19 | 15.9 | 33.11 | 17.61 | 49.48 | 20.97 | 50.69 | 20.27 |
| 6 | YaraBela Sulfan 125.0025 kg/ha | 36.26 b | 18.26 ab | 51.06 | 25.27 | 49.25 | 18.39 | 32.06 | 17.77 | 48.17 | 20.18 | 50.35 | 19.21 |
| Mean | | 36.17 | 18.18 | 50.79 | 25.3 | 47.6 | 16.81 | 31.03 | 16.35 | 47.66 | 19.71 | 49.21 | 18.73 |
| L.S.D | | 3.15 | 1.65 | 4.41 Ns | 2.19 Ns | 5.59 Ns | 3.57 Ns | 6.56 Ns | 4.13 Ns | 10.03 Ns | 4.90 Ns | 10.64 Ns | 5.32 Ns |
| CV (%) | | 6.77 | 7.05 | 6.75 | 6.74 | 9.12 | 16.5 | 11.62 | 13.89 | 11.57 | 13.68 | 11.89 | 15.63 |

*Means in a column followed by different letter(s) differ significantly (P <0.05) based on Duncan's New Multiple Range Test; Ns = Non-significant.*

**Table 5: Effect of different rates of top dressing fertilizers on bottom, middle and top leaves – 2017/2018 for Kahama and Chunya sites**

| Tr. no | Treatment name | Kahama site | | | | | | Chunya site | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Bottom leaf | | Middle leaf | | Top leaf | | Bottom leaf | | Middle leaf | | Top leaf | |
| | | Length (cm) | Width (cm) | Length (cm) | Width (cm) | Length (cm) | Width (cm) | Length (cm) | Width (cm) | Length (cm) | Width (cm) | Length (cm) | Width (cm) |
| 1 | CAN 27% 125 kg/ha | 36.18 b | 18.79 ab | 52.52 | 26.8 | 48.55 | 24.22 | 28 | 14.84 | 46.64 | 18 | 48.78 | 21.53 |
| 2 | YaraLiva nitrabor 66.668 kg/ha | 40.00 a | 21.80 a | 50 | 24.62 | 44.88 | 22.96 | 30.46 | 14.98 | 48.55 | 23.26 | 49.6 | 22.26 |
| 3 | YaraLiva nitrabor 125 kg/ha | 36.86 b | 18.44 ab | 47.36 | 23.16 | 48.9 | 22 | 31.08 | 15.04 | 48.86 | 24.7 | 48.68 | 22.43 |
| 4 | YaraBela Sulfan 55 kg/ha plus YaraLiva nitrabor 83.335 kg/ha | 33.94 b | 16.16 b | 54.88 | 26 | 48.89 | 23.31 | 31 | 15 | 48.94 | 24.86 | 50 | 23.68 |
| 5 | YaraMila tobacco 310.0062 kg/ha | 36.00 b | 18.00 ab | 51.9 | 26.7 | 44 | 20.99 | 31.34 | 15.02 | 51.88 | 25 | 51.29 | 21.22 |
| 6 | YaraBela Sulfan 125.0025 kg/ha | 36.87 b | 18.46 ab | 56.08 | 28 | 50.55 | 24.99 | 33 | 16.56 | 49.99 | 24.16 | 52.99 | 18.23 |
| Mean | | 30.14 | 15.12 | 50.98 | 26.4 | 48.7 | 17 | 33 | 17 | 47.98 | 19.98 | 46.88 | 19 |
| L.S.D | | 3 | 1.5 | 4.68 Ns | 2.64 Ns | 5.60 Ns | 3.09 Ns | 5.68 Ns | 4.00 Ns | 12.03 Ns | 6.92 Ns | 18.24 Ns | 6.22 Ns |
| CV (%) | | 8.94 | 9 | 8.8 | 6.9 | 9.99 | 18 | 16 | 11.99 | 14.47 | 14.66 | 19.89 | 19.99 |

*Means in a column followed by different letter(s) differ significantly (P <0.05) based on Duncan's New Multiple Range Test; Ns = Non-significant.*

### 3.2 DRY LEAF YIELD

Results (Table 5) showed that the highest dry leaf yield for three cropping seasons were achieved with application of treatment N:P:K 10:18:24 310 kg/ha which gave mean weights of 2,144.58 and 2040.79 kg/ha, and 1904.86 kg/ha for Tumbi site during the 2013/2014 and 2014/2015 cropping seasons, respectively. On the other hand, the highest barn dry weights were measured with the same treatment resulting into 2166.67 kg/ha in Chunya and 2225.00 kg/ha in Kahama. This was followed by treatment YaraBela Sulfan 125 kg/ha which gave mean weights of 2049.55 and 1904.86 kg/ha during the 2013/14 and 2014/15, respectively at Tumbi and 2225.00 kg/ha in Chunya and 2055.00 kg/ha in Kahama during 2017/2018. The lowest yields were recorded in treatment in CAN 27% 125 kg/ha which gave mean weights of 1824.18 and 1720.37 kg/ha for the 2013/14 and 2014/15 cropping seasons, respectively, at Tumbi and 1822.12 kg/ha in Chunya and 1856.00 kg/ha in Kahama during the 2017/2018 cropping season. There were no significance ($P$ >0.05) differences among all treatments.

The reason for NPK 10:18:24 310 kg/ha to produce the highest barn dry yield could be attributed to the highest amounts of N, P, and K supplied to the individual tobacco plant. In this treatment 18.6 g of NPK 10:18:24 was supplied per plant as top dressing and 30 g/plant during sowing as basal dressing. Positive effects of application of NPK fertilizer on dry leaf weight were also reported by Liu (1998) and Rostami (1997). Furthermore, treatment YaraBela Sulfan 7.5 g/plant yielded higher than treatment CAN 27% 7.5 g/plant despite the lower amount of N contained in the former treatment (See Table 1). This is probably due to the higher amount of nutrient sulphur (42.5 kg/ha) than that in treatment CAN 27% 7.5 g/plant (35 kg/ha). In addition, soil analysis results (Table 2) revealed that there was inadequate sulphur, which might have caused inefficient use of nitrogen by tobacco plants treated with CAN 27% 7.5 g/plant compared with YaraBela Sulfan 7.5 g/plant. According to Smith (1987), the recommended N: S ratio in flue cured tobacco is 83:34 kg/ha, which is not balanced in these two treatments.

### 3.3 GRADE INDEX

Grade index (GI) is the ratio of the value of tobacco in the market over the dry barn weight, that is, the weight of tobacco after curing process before grading. Tobacco of good quality has high grade index while the low quality tobacco fetches low price which also gives low GI.

$$\text{Grade index (GI)} = \frac{\text{Grade value} \times \text{graded tobacco weight}}{Barn\ dry\ weight\ of\ leaves}$$

The results (Table 5) indicated that the highest grade index was obtained from treatment YaraBela Sulfan 55 kg/ha plus YaraLiva Nitrabor 83.335 kg/ha) which was $2 followed by treatment CAN 27% 125 kg/ha was $1.83 for the 2013/14 cropping season. During the 2014/15 cropping season, the highest grade index was $1.94 recorded in treatment YaraBela Sulfan 3.3 g/plant plus YaraLiva nitrobor 5 g/plant followed by $1.72 in treatment YaraBela Sulfan 7.5 g/plant. In both cropping seasons tobacco with low quality had grade indices of $1.23 and $1.20 for the 2013/14 and 2014/15, respectively.

During the 2017/018 cropping season, the highest grade index was $2.3 obtained from treatment YaraBela Sulfan 55 kg/ha followed by $2.20 recorded in treatment YaraBela Sulfan 125 kg/ha. On the other hand, the lowest grade index was $1.6 obtained from treatment YaraLiva Nitrobor 125 kg/ha. The treatments differed significantly ($P$<0.05). The high grade index in treatment could be attributed to the high concentrations of N, P, and K in cured middle leaves (Table 6) which was slightly above the sufficiency range (Appendix 1). Sulphur was within sufficiency range. Nutrients within and above sufficiency ranges might have contributed to the high grade index in treatment four because grade index increases with increase in nutrients concentration. Treatment YaraBela Sulfan 3.3 g/plant plus YaraLiva nitrobor 5 g/plant differed significantly ($P$< 0.05) from other treatments.

**Table 6: Effect of different rates of top dressing fertilizers on Barn dry weight yield and grade index for on-station**

| Treatment | Tumbi | | | | Chunya | | Kahama | |
|---|---|---|---|---|---|---|---|---|
| | 2013/2014 | | 2014/2015 | | 2017/2018 | | 2017/2018 | |
| | Barn dry weight (kg/ha) | Grade index | Barn dry weight (kg/ha) | Grade index | Barn dry weight (kg/ha) | Grade index | Barn dry weight (kg/ha) | Grade index |
| CAN 27% 125 kg/ha | 1824.18 | 1.83b | 1720.37 | 1.69b | 1822.12 | 1.87b | 1856 | 1.88b |
| YaraLiva nitrabor 66.668 kg/ha | 1996.56 | 1.32b | 1748.67 | 1.31b | 1985.88 | 1.77b | 1998.66 | 1.86b |
| YaraLiva nitrabor 125 kg/ha | 1894.94 | 1.42b | 1818.47 | 1.41b | 1876.24 | 1.46b | 1885.55 | 1.60b |
| YaraBela Sulfan 3.3 g/plant plus YaraLiva nitrobor 5 g/plant | 1916.62 | 2.00 a | 1826.21 | 1.94a | 1919.92 | 2.23a | 1987.65 | 2.30a |
| YaraMila tobacco 310 kg/ha | 2144.58 | 1.23b | 2040.79 | 1.2b | 2166.67 | 1.80b | 2225 | 1.99b |
| YaraBela Sulfan 125 kg/ha | 2049.56 | 1.75b | 1904.86 | 1.72b | 2045.87 | 1.801b | 2055 | 2.2b |
| Mean | 1971.07 | 1.69 | 1843.23 | 1.545 | 1978.66 | 1.77 | 1986 | 1.8 |
| L.S.D | 278.75 Ns | 0.61 | 261.02 | 0.658Ns | 274.86Ns | 0.66 | 277 | 0.54 |
| CV (%) | 10.99 | 22.56 | 19.43 | 27.71 | 12.64 | 20.88 | 22.65 | 21 |

*Means in a column followed by different letter(s) differ significantly (P <0.05) based on Duncan's New Multiple Range Test; Ns = Non-significant.*

### 3.4 NICOTINE AND NUTRIENT CONCENTRATIONS IN FLUE CURED TOBACCO LEAVES

Nutrient concentrations in the tobacco plant leaves were determined in the laboratory and compared with sufficiency ranges (Appendix 1) prepared in the Southern region of United States of America (Campbell, 2008).

#### 3.4.1 NITROGEN

In both 2013/2014 and 2014/2015 cropping seasons the results were not significant (P >0.05). However, the highest concentration of N was 2.46% obtained from application of YaraLiva Nitrabor 125 kg/ha followed by 2.42% in CAN 27% 125 kg/ha. On the other hand, the lowest concentration of nitrogen was 2.04% obtained from an application of YaraLiva Nitrobor 66.66 kg/ha. In all treatments the results indicated that the amount of nitrogen was slightly higher than the normal sufficient range of nitrogen in flue cured tobacco middle leaves (see Appendix 1).

The 2014/15 cropping season resulted into highest concentration of nitrogen of 2.42% in YaraLiva Nitrabor 125 kg/ha followed by 2.39% in CAN 27% 125 kg/ha. The lowest concentration of nitrogen was 2.00% obtained from an application of YaraLiva Nitrabor 66.66 kg/ha. With exception of treatment YaraLiva nitrobor 4 g/plant, all other treatments resulted into relatively higher concentrations of nitrogen than the sufficient range in flue cured tobacco middle leaves (see Appendix 1).

#### 3.4.2 PHOSPHORUS

Results were not significant ($P$> 0.05) for all treatments during the 2013/2014 and 2014/2015 cropping seasons. However, the highest concentration of phosphorus was 1.43% obtained from an application of NPK 310 kg/ha. This is probably caused by high supply of phosphorus which was 145.8 kg/ha followed by 1.31% from YaraBela Sulfan 125 kg/ha. The lowest concentration of phosphorus was 0.16% obtained from an application of YaraBela Sulfan 55 kg/ha plus YaraLiva Nitrobor 83.33 kg/ha. The amount of phosphorus was within the sufficient range for treatments CAN 27% 7.5 g/plant, YaraLiva nitrabor 4 g/plant, and YaraLiva nitrabor 7.5 g/plant. However, it was above the sufficient range for the treatments YaraBela Sulfan 3.3 g/plant plus YaraLiva Nitrabor 5 g/plant, YaraMila tobacco 18.6 g/plant, and YaraBela Sulfan 7.5 g/plant (Appendix 1).

During the 2014/15 cropping season the highest concentration of phosphorus was 1.40% obtained from an application of NPK 310 kg/ha. This is probably caused by high supply of phosphorus which was 145.8 kg/ha followed by .29% in YaraBela Sulfan 125 kg/ha. The lowest concentration of phosphorus was 0.17% obtained from an application of YaraBela Sulfan 55 kg/ha plus YaraLiva Nitrobor 83.33 kg/ha. The concentration of phosphorus in tobacco leaves during this period was within the sufficient range for the treatments the treatments YaraBela Sulfan 3.3 g/plant plus YaraLiva Nitrobor 5 g/plant, YaraMila tobacco 18.6 g/plant, and YaraBela Sulfan 7.5 g/plant (Appendix 1).During the 2017/2018 cropping season the concentration of phosphorus in tobacco leaves following application of treatments was in the decreasing magnitude of YaraMila tobacco 310 kg/ha, YaraBela Sulfan 125 kg/ha, YaraBela Sulfan 55 kg/ha plus YaraLiva Nitrabor 83.33 kg/ha, CAN 27% 125 kg/ha, YaraLiva Nitrabor 66.66 kg/ha, and YaraLiva Nitrabor 125 kg/ha.

**3.4.3 POTASSIUM** During both the 2013/2014 and 2014/2015 cropping seasons the results were not significant ($P > 0.05$). The highest concentration of potassium was 2.41% obtained from an application of CAN 27% 125 kg/ha followed by 2.36% in YaraBela Sulfan 125 kg/ha. The lowest concentration of potassium was 2.05% obtained from an application of YaraLiva Nitrabor 66.6 kg/ha. In all treatments the concentration of potassium was within the normal sufficient range (Appendix 1).

During the 2014/15 cropping season, the highest concentration of potassium was 2.37% obtained from an application of CAN 27% 125 kg/ha followed by 2.29% In YaraBela Sulfan 125 kg/ha. The lowest concentration of potassium was 2.00% obtained from an application of YaraLiva Nitrabor 66.6 kg/ha. In all treatments the concentration of potassium was within the sufficient range.

During the 2017/2018 cropping season the concentration of potassium in tobacco leaves following application of treatments was in the decreasing order of CAN 27% 125 kg/ha, YaraBela Sulfan 55 kg/ha plus YaraLiva Nitrabor 83.33 kg/ha, YaraLiva Nitrabor 125 kg/ha, YaraMila tobacco 310 kg/ha, YaraBela Sulfan 125 kg/ha, and YaraLiva Nitrobor 66.66 kg/ha.

### 3.4.4 SULPHUR

In both 2013/2014 and 2014/2015 cropping seasons the results were not significant ($P > 0.05$). The highest concentration of sulphur was 0.46% obtained from an application of NPK 10:18:24 310 kg/ha followed by 0.36% in YaraBela Sulfan 125 kg/ha. The lowest concentration of sulphur was 0.17% obtained from an application of YaraLiva Nitrabor 66.6 kg/ha. In all treatments the amount of sulphur was within the sufficient range (Appendix 1).

During the 2014/15 cropping season the highest concentration of sulphur was 0.42% obtained from an application of NPK 10:18:24 310 kg/ha followed by 0.34% YaraBela Sulfan 125 kg/ha. 0.170% obtained from an application of YaraLiva Nitrabor 66.6 kg/ha. In all treatments the amount of sulphur was within the sufficient The lowest concentration of sulphur was range (Appendix 1).

During the 2017/2018 cropping season the concentration of sulphur in tobacco leaves following application of treatments was in the decreasing order of YaraMila tobacco 310 kg/ha, YaraBela Sulfan 125 kg/ha, YaraBela Sulfan 55 kg/ha plus YaraLiva Nitrabor 83.33 kg/ha, CAN 27% 125 kg/ha, YaraLiva Nitrabor 125 kg/ha, and YaraLiva Nitrabor 66.66 kg/ha.

### 3.4.5 NICOTINE CONTENT

In both 2013/2014 and 2014/2015 cropping seasons the results were not significant ($P > 0.05$). The highest concentration of nicotine was 4.13% obtained from an application of YaraLiva Nitrabor 125 kg/ha followed by 3.99% in YaraBela Sulfan 125 kg/ha. The lowest nicotine content was 3.19% obtained from an application of YaraLiva Nitrabor 66.6 kg/ha.

During the 2014/15 cropping season the highest concentration of nicotine was 4.00% obtained from an application of YaraLiva Nitrabor 125 kg/ha followed by 3.91% in YaraBela Sulfan 125 kg/ha. The lowest amount of nicotine was 3.12% obtained from an application of YaraLivaNitrabor 66.6 kg/ha.

During the 2017/2018 cropping season the contents of nicotine in tobacco leaves following application of treatments was in the decreasing order of YaraLiva Nitrabor 125 kg/ha, YaraBela Sulfan 125 kg/ha, CAN 27% 125 kg/ha, YaraMila tobacco 310 kg/ha, YaraBela Sulfan 55 kg/ha plus YaraLiva Nitrabor 83.33 kg/ha, and YaraLiva Nitrabor 66.66 kg/ha.

**Table 7: Nicotine and nutrient concentrations in flue cured tobacco leaves**

| | | 2013/14 Results | | | | | 2014/15 Results | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tr. no | Treatment | Nitrogen | Phosphorus | Potassium | Sulphur | Nicotine | Nitrogen | Phosphorus | Potassium | Sulphur | Nicotine |
| 1 | CAN 27 125 kg/ha | 2.42 | 0.24 | 2.41 | 0.293 | 3.73 | 2.39 | 0.21 | 2.37 | 0.26 | 3.69 |
| 2 | YaraLiva nitrabor 66.66 kg/ha | 2.04 | 0.193 | 2.05 | 0.176 | 3.19 | 2 | 0.181 | 2 | 0.17 | 3.12 |
| 3 | YaraLiva nitrabor 125 kg/ha | 2.46 | 0.19 | 2.26 | 0.24 | 4.13 | 2.42 | 0.17 | 2.21 | 0.2 | 4 |
| 4 | YaraBela Sulfan 55 kg/ha plus YaraLiva nitrabor 83.33 kg/ha | 2.38 | 1.166 | 2.36 | 0.31 | 3.47 | 2.3 | 1.159 | 2.29 | 0.29 | 3.41 |
| 5 | YaraMila tobacco 310 kg/ha | 2.31 | 1.43 | 2.216 | 0.46 | 3.57 | 2.21 | 1.4 | 2.19 | 0.42 | 3.52 |
| 6 | YaraBela Sulfan 125 kg/ha | 2.4 | 1.31 | 2.086 | 0.36 | 3.99 | 2.38 | 1.29 | 2.01 | 0.34 | 3.91 |
| | Mean | 2.34 | 0.58 | 2.23 | 0.307 | 3.6 | 2.28 | 0.568 | 2.178 | 0.28 | 3.6 |
| | LSD | 0.79 Ns | 2.62 Ns | 1.105 Ns | 0.26 Ns | 1.937 Ns | 0.72 Ns | 2.58 Ns | 1.01 Ns | 0.21 Ns | 1.921Ns |
| | CV % | 13 | 172.13 | 19.11 | 33.14 | 20.3 | 11.9 | 169.25 | 18.5 | 30.02 | 19.89 |

*Means in a column followed by different letter(s) differ significantly (P <0.05) based on Duncan's New Multiple Range Test; Ns = Non-significant.*

**Table 8: Nicotine and nutrient concentrations in flue cured tobacco leaves for on-farm experiment during the 2017/018 cropping season**

| Tr. no | Treatments | 2017/2018 cropping season | | | | |
|---|---|---|---|---|---|---|
| | | Nitrogen | Phosphorus | Potassium | Sulphur | Nicotine |
| 1 | CAN 27% 125 kg/ha | 2.405 | 0.225 | 2.39 | 0.27 | 3.71 |
| 2 | YaraLiva nitrabor 66.66 kg/ha | 2.02 | 0.187 | 2.025 | 0.17 | 3.15 |
| 3 | YaraLiva nitrabor 125 kg/ha | 2.44 | 0.18 | 2.23 | 0.22 | 4.06 |
| 4 | YaraBela Sulfan 55 kg/ha plus YaraLiva nitrabor 83.33 kg/ha | 2.34 | 1.16 | 2.32 | 0.3 | 3.44 |
| 5 | YaraMila tobacco 310 kg/ha | 2.26 | 1.41 | 2.2 | 0.44 | 3.54 |
| 6 | YaraBela Sulfan 125 kg/ha | 2.39 | 1.3 | 2.04 | 0.35 | 3.95 |
| | Mean | 2.31 | 0.57 | 2.2 | 0.29 | 3.6 |
| | LSD | 0.755Ns | 2.58Ns | 1.11Ns | 0.21Ns | 1.92Ns |
| | CV % | 12.45 | 17.69 | 18.81 | 31.58 | 20.09 |

*Means in a column followed by different letter(s) differ significantly (P <0.05) based on Duncan's New Multiple Range Test; Ns = Non-significant.*

## 3.5 ECONOMIC ANALYSIS OF NEWLY INTRODUCED TOP DRESSING FERTILIZERS

Gross margin analysis was done in order to assess the economic implication of the use of the new introduced top dressing fertilizers. The results in Tables 8 and 9 showed that for on-station and on-farm experiments higher gross margin was obtained from treatment YaraBela Sulfan 55 kg/ha plus YaraLiva Nitrobor 83.33 kg/ha which was 1,192.24 and $895.92 for the 2013/14 and 2014/15 cropping seasons, respectively. This was followed by 955.90 and $639.59 in treatment YaraBela Sulfan 125 kg/ha during the 2013/14 and 2014/15 cropping seasons, respectively. For the on-farm experiment, during the 2017/018 cropping season the highest gross margins were 1,912.69 and 1,872.37$ for the treatments YaraBela Sulfan 3.3 g/plant plus YaraLiva Nitrabor 5 g/plant and YaraBela Sulfan 7.5 g/plant, respectively. The best explanation for this could be attributed to the high quality of tobacco produced with the application of these two treatments. These findings are consistent with those found in grade index which was also high in these two treatments.

**Table 9: Economic analysis of the newly introduced top dressing fertilizers for the on-station experiment 2013/014-2015/016**

| Treatment name | 2013/14 | | | | | 2014/15 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total COP ($/ha) | Yield (kg/ha) | Grade index | Total revenue ($/ha) | Total margin ($/ha) | Total COP ($/ha) | Yield (kg/ha) | Grade index | Total revenue ($/ha) | Total margin ($/ha) |
| CAN 27% 125 kg/ha | 2,640.89 | 1824.18 | 1.83 | 3,338.25 | 697.36 | 2,647.92 | 1720.37 | 1.69 | 2,907.43 | 259.54 |
| YaraLiva nitrabor 66.668 kg/ha | 2,599.21 | 1996.56 | 1.32 | 2,635.46 | 36.25 | 2,605.14 | 1748.67 | 1.31 | 2,290.76 | -314.38 |
| YaraLiva nitrabor 125 kg/ha | 2,634.56 | 1894.94 | 1.42 | 2,690.81 | 56.25 | 2,640.49 | 1818.47 | 1.41 | 2,564.04 | -76.45 |
| YaraBela Sulfan 55 kg/ha plus YaraLiva nitrabor 83.335 kg/ha | 2,641.00 | 1916.62 | 2 | 3,833.24 | 1,192.24 | 2,646.93 | 1826.21 | 1.94 | 3,542.85 | 895.92 |
| YaraMila tobacco 310 kg/ha | 2,878.23 | 2144.58 | 1.23 | 2,637.83 | -240.40 | 2,884.16 | 2040.79 | 1.2 | 2,448.95 | -435.22 |
| YaraBela Sulfan 125 kg/ha | 2,630.84 | 2049.56 | 1.75 | 3,586.73 | 955.90 | 2,636.77 | 1904.86 | 1.72 | 3,276.36 | 639.59 |

**Key:** COP = cost of production

**Table 10: Economic analysis of the newly introduced top dressing fertilizers for the on-farm experiment for the 2017/018 cropping season**

| **Treatment name** | 2017/08 | | | | | 2017/018 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total COP ($/ha) | Yield (kg/ha) | Grade index | Total revenue ($/ha) | Total margin ($/ha) | Total COP ($/ha) | Yield (kg/ha) | Grade index | Total revenue ($/ha) | Total margin ($/ha) |
| CAN 27% 125 kg/ha | 2,654.95 | 1822.12 | 1.87 | 3,407.36 | 752.41 | 2,661.98 | 1856 | 1.88 | 3,489.28 | 827.30 |
| YaraLiva nitrabor 66.668 kg/ha | 2,611.07 | 1985.88 | 1.77 | 3,515.01 | 903.94 | 2,617.00 | 1998.66 | 1.86 | 3,717.51 | 1,100.51 |
| YaraLiva nitrabor 125 kg/ha | 2,646.42 | 1876.24 | 1.46 | 2,739.31 | 92.89 | 2,652.35 | 1885.55 | 1.6 | 3,016.88 | 364.53 |
| YaraBela Sulfan 55 kg/ha plus YaraLiva nitrabor 83.335 kg/ha | 2,652.86 | 1919.92 | 2.23 | 4,281.42 | 1,628.56 | 2,658.79 | 1987.65 | 2.3 | 4,571.48 | 1,912.69 |
| YaraMila tobacco 310 kg/ha | 2,890.09 | 2166.67 | 1.8 | 3,900.01 | 1,009.92 | 2,896.02 | 2225 | 1.9 | 4,227.50 | 1,531.73 |
| YaraBela Sulfan 125 kg/ha | 2,642.70 | 2045.87 | 1.801 | 3,684.61 | 1,041.91 | 2,648.63 | 2055 | 2.2 | 4,521.00 | 1,872.37 |

**Key:** COP = cost of production

## 4.0 CONCLUSION AND RECOMMENDATIONS

Nitrogen, phosphorus, and potassium constitute the primary macronutrients while calcium and sulphur (and magnesium not involved in this study) constitute the secondary macronutrients. These are also among the essential nutrient elements required for optimization of yield productivity and quality of nicotine in tobacco. For the case of micronutrients such as Fe, Mn, Cu, Mo, Zn, and B, the normal administration of B leads to yield increases and improves the colouring of the leaves. YaraLiva Nitrobor 125 kg/ha indicated to have influenced higher leaf area of primings and suppresses development of suckers. The highest dry leaf yields were derived from N:P:K 10:18:24 310 kg/ha with weights of 2144.58 and 2040.79 kg/ha for the 2013/14 and 2014/15 cropping seasons, respectively. This was followed by YaraBela Sulfan 125 kg/ha which yielded 2049.55 and 1904.86 for the same 2013/14 and 2014/15 cropping seasons, respectively. The lowest yields was generated from treatment CAN 27% 125 kg/ha which were 1824.18 and 1720.37 for the 2013/14 and 2014/15, cropping seasons, respectively.

The 207/018 on-farm experiment gave the highest yield was 2045.87 kg/ha in YaraMila tobacco (N:P:K 10:18:24, 310 kg/ha) followed 2055.00 kg/ha by the YaraBela Sulfan 125 kg/ha. The tobacco with relatively higher quality was obtained from a combination of YaraBela Sulfan 55 kg/ha and YaraLiva Nitrabor 83.34 kg/ha. Economic analysis revealed that for on-station as well as on-farm experiments the higher gross margins were attained with basal application of NPK 10:18:24 at a rate of 500 kg/ha and top dressed with a combination of YaraBela Sulfan 55 kg/ha and YaraLiva Nitrabor 83.34 kg/ha. The lowest gross margin was obtained with basal application of NPK 10:18:24 at a rate of 500 kg/ha when top dressed with NPK 10:18:24 at a rate of 310 kg/ha. YaraBela Sulfan (CAN 24% + 6% S) at a rate of 125 kg/ha performed better than CAN 27% at a rate of 125 kg/ha in terms of quantity and quality of tobacco. Hence, it is economically viable to use CAN 24% + 6% S in top dressing flue cured tobacco.

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**Appendix 1: Reference of sufficiency ranges of macro and micro nutrients of flue cured tobacco leaves for Southern region of the United State of America**

| **Macronutrients (%)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Growth stage | Tissue | **N** | **P** | **K** | **Ca** | **Mg** | **S** |
| Seedling | MRML | 4.0 - 6.0 | 0.2 - 0.5 | 3.0– 4.0 | 0.6- 1.5 | 0.2-0.6 | 0.15-0.6 |
| Early growth | MRML | 4.0 - 5.0 | 0.2 - 0.5 | 2.5 - 3.5 | 0.75-1.5 | 0.2-0.6 | 0.15-0.6 |
| Flowering | MRML | 3.5 - 4.5 | 0.2 - 0.5 | 2.5 - 3.5 | 0.75-1.5 | 0.2-0.6 | 0.15-0.6 |
| Maturity | MRML | 2.25 – 3.0 | 0.17-0.5 | 1.6 -3.0 | 0.75-1.5 | 0.2-0.6 | 0.15-0.6 |
| Harvest | Upper leaf | 2.0 – 2.25 | 0.14-0.3 | 1.5– 2.5 | 0.75-1.5 | 0.2-0.6 | 0.15-0.4 |
| Harvest | Middle leaf | 1.6 – 2.0 | 0.13- 0.3 | 1.5– 2.5 | 1.0-2.0 | 0.2-0.6 | 0.15-0.4 |
| Harvest | Lower leaf | 1.3 - 1.75 | 0.12- 0.3 | 1.3-2.5 | 1.0-2.5 | 0.18-0.75 | 0.15-0.4 |

| **Micronutrients (ppm)** | | | | | | |
|---|---|---|---|---|---|---|
| Growth stage | Tissue | **Fe** | **Mn** | **Zn** | **Cu** | **B** |
| Seedling | MRML | 50-300 | 20-250 | 20-60 | 5-10 | 18-75 |
| Early growth | MRML | 50-300 | 20-250 | 20-60 | 5-10 | 18-75 |
| Flowering | MRML | 50-300 | 20-250 | 20-60 | 5-10 | 18-75 |
| Maturity | MRML | 50-300 | 20-250 | 20-60 | 5-10 | 18-75 |
| Harvest | Upper leaf | 40-200 | 20-350 | 18-60 | 5-10 | 18-30 |
| Harvest | Middle leaf | 40-200 | 20-350 | 18-60 | 4-10 | 18-30 |
| Harvest | Lower leaf | 40-200 | 18-350 | 18-60 | 3-10 | 15-30 |

Source: Southern Cooperative Series Bulletin (SCSB)
MRML: Most recent mature leaf (2009)