YIELD OF MAIZE AS AFFECTED BY FERTILIZER APPLICATION PRACTICES

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ABSTRACT

A study was conducted at Bunda College during the 2003/04 crop season to assess the effect of fertilizer application practices on performance of maize with emphasis on improving the efficiency of using urea as a top dressing fertilizer. The treatments were laid out as a split-plot in a randomized complete block design (RCBD) with maize varieties as main plots and fertilizer application practices as subplots. There were three maize varieties and three fertilizer application practices. The maize varieties included local maize, Masika (composite) and DK8031 (hybrid) and the fertilizer application practices were 100 kg ha⁻¹ 23:21:0 + 4S + 50 kg ha⁻¹ urea as basal and 100 kg ha⁻¹ urea as top dressing (Pᵢ), 100 kg ha⁻¹ 23:21:0 + 4S + 75 kg ha⁻¹ urea as basal and 75 kg ha⁻¹ urea as top dressing (Pᵢ) and 100 kg ha⁻¹ 23:21:0 + 4S basal and 150 kg ha⁻¹ urea as top dressing (Pᵢ).

There were significant differences in grain yield among the maize varieties (p=0.004) and fertilizer application practices (p=0.001). DK8031 yielded highest (6313 kg/ha) followed by Masika (5467 kg/ha) and local maize (4323 kg/ha). Pᵢ increased maize grain yields by 16-29% over Pᵢ (5422 kg/ha) and Pᵢ (4891 kg/ha) respectively. Similar findings were obtained on the 100 seed weight with Pᵢ having the highest 100 seed weight (39 g) as compared to Pᵢ (37 g) and Pᵢ (35 g). However, fertilizer application practices had no effect on lodging, cob height and plant height of the maize varieties. The results from this study suggest that when using Urea as a top dressing fertilizer, application of half of the dose as part of the basal fertilizer and the remaining half as top dressing fertilizer increase maize grain yield.

Keywords: maize, urea, basal and top dressing fertilizer

INTRODUCTION

Maize (Zea mays) is the staple cereal crop to over 80% of the Malawian population and is grown on 75 to 85% of the arable land (Anonymous, 1998). Farmers in Malawi grow hybrid, composite and local maize varieties. The current average yield for subsistence farmers is about 1.3 t/ha due to a number of factors such as low soil fertility, pests and diseases, droughts. Yields of up to 8000 kg/ha for hybrid, 5000 kg/ha for composites and 3000 kg/ha for local varieties can be attained with good crop management practices (Guide to Agricultural Production, 2003; Sakala and Kabambe, 2004).

Crops require nutrient elements in order to carry out various physiological processes. Optimal fertilizer requirements depend on the productive potential of the cultivar, the previous cropping history and the general fertility of the fields used. In general, the fertilizer requirements for maize in tropical conditions is about 100-120 kg N/ha, 40 kg P/ha and 50 kg K/ha (Yayock et al, 1988). A number of studies have been done on the rates and means of application of fertilizers (Cooke, 1972; Arison, 1997; Mughogho et al, 1986). Timing application of fertilizer and the way in which it is applied is important for good crop growth and yield. There are several factors that affect the efficiency of inorganic fertilizer application and they include soil moisture regime, soil aeration, hereditary characteristics, plant population and timing of fertilizer application (Anion, 1972). In Malawi, the recommended fertilizer application practice in maize is basal dressing soon after emergence with 23:21:0 + 4S at 100 kg/ha. Basal dressing is important to enable the plants develop an extensive root system which can help the plant withstand drought stress and absorb nutrients. Top dressing is followed three weeks later with either Calcium Ammonium Nitrate (CAN) at 200 kg/ha or Urea at 150 kg/ha. Urea (NH₂CO₂ NH₂) is a high analytical fertilizer and contains about 46% N. Darren et al, (2000) indicated that the most logical approach to increasing N fertilizer use efficiency is to supply N as it is needed by the crop in order to reduce the opportunity for N loss.

The NH₄⁺ ion in ammonical fertilizer is partially adsorbed on soil colloids and its uptake rate is usually lower than NO₃⁻ under field conditions.

Nitrogen is one of the nutrients that is required in plant growth and development (Arnon, 1972; and Harper, 1983). Plants take nitrogen as nitrate (NO₃⁻) or ammonium (NH₄⁺) ions. However, for maize, nearly all N is absorbed in the form of NO₃⁻ (Samuel et al., 1965, Tisdale, 1974). When urea is applied as a top dressing fertilizer, it undergoes several processes before the maize can take it up as opposed to CAN. Such processes include hydrolysis to form ammonium carbonate which is further oxidized to form nitrates as shown in the reaction below:

\[ \text{NH}_2\text{CONH}_2 + 2\text{H}_2\text{O} \text{hydrolysis (NH}_3\text{)}_2\text{CO}_3 \]
\[ \text{NH}_4^+ \text{CO}_3^- + 4\text{H}^+ + 2\text{H}_2\text{O} \text{nitrification} 2\text{NO}_3^- + 2\text{H}_2\text{Q} + 2\text{H}^+ + \text{CO}_2 \]
During hydrolysis, ammonia gas may also be generated and lost into the air as in the reaction below: \((\text{NH}_2)_2\text{CO} \cdot \text{H}_2\text{O}\) hydrolysis \(2\text{NH}_3 + \text{CO}_2\).

This takes place when the Urea is not fully incorporated into the soil (Bolton and Bennett, 1975). Because of the above processes, most crops do not respond quickly to NHT fertilizers as to N\(_2\) applications and hence need proper management and timing during application (Ray, 1985). The objective of this study therefore was to assess the performance of maize under different application practices of urea fertilizer.

**MATERIALS AND METHODS**

**Site.**
A field experiment was conducted at Bunda College during the 2003/04 crop-growing season. Bunda College is at latitude of 14° 35' S, longitude 33° 50' E and an altitude of 1159 m above sea level. It receives an annual rainfall of about 1031 mm. Rainfall is of unimodal pattern falling between November and April or May with virtually no precipitation during the rest of the year (Mac Coll, 1990).

**Experimental design and layout.**
The experiment was laid out as a split plot in a randomized complete block design (RCBD) with maize varieties as main plots and fertilizer application practices as subplots. Three varieties of maize were grown namely DK8031 (Hybrid), Masika (composite) and Local. Each treatment was replicated three times. The treatments were as follows:

a. Maize Varieties
   1. DK8031 (Hybrid)
   2. Masika (Composite)
   3. Local maize

b. Fertilizer Application Practices
   1. 100 kg ha\(^{-1}\) 23: 21: 0 +4S +50 kg ha\(^{-1}\) urea as basal and 100 kg ha\(^{-1}\) urea as top dressing. (P1)
   2. 100 kg ha\(^{-1}\) 23:21:0+4S + 75 kg ha\(^{-1}\) urea as basal and 75 kg ha\(^{-1}\) urea as top dressing. (P2)
   3. 100 kg ha\(^{-1}\) 23:21:0 +4S basal and 150 kg ha\(^{-1}\) urea as top dressing (P3)

The rates of fertilizer were based on area specific fertilizer recommendations for maize in Lilongwe RDP's (MPTF, 1999) i.e. 92:21:0+4S if production is for home consumption.

**Field operations.**
Planting was done on 6\(^{th}\) December 2003 with 4 seeds per hill spaced at 75cm between planting stations. Later after germination they were thinned to 3 seeds per hill. Basal dressing was carried out a week after planting, according to the treatments using dollop method of application. Top dressing was followed three weeks after the basal fertiliser. All other agronomic practices were done accordingly. Growth was monitored from germination till harvesting. Biomass and grain yield were determined at harvesting. Harvest index was calculated for each treatment as follows:

**Data collection and analysis**
Data were collected from the net plot that constituted of the 3 middle ridges discarding 1m from both ends. The following data was collected: plant height, cob height, grain yield, biomass yield, 100 seed weight and lodging score (a scale of 1-5 was used where 1 = upright and 5 = prostrate). All collected data were subjected to analysis of variance using Genstat 5 Release 3 statistical package (Payne, 1993) and LSD tests were done to determine find differences between treatment means.

**RESULTS AND DISCUSSION**

**Maize grain yields under different fertilizer application practices during the 2003/04 crop season.**
There were significant differences in grain yield among the maize varieties (p<0.004) and fertilizer practices (p = 0.001) (Table 1). DK8031 was the highest yielder (6313 kg/ha) followed by Masika (5467 kg/ha) and then local maize (4823 kg/ha). This is in agreement with Chilimba (1889) and Mphande (1994) who indicated that hybrids are better users of both the soil and applied N than the composite and local maize. A combination of 100 kg ha\(^{-1}\) 21-0-4S + 75 kg ha\(^{-1}\) urea as basal and 75 kg ha\(^{-1}\) urea as top dressing (P2) gave the highest yield of 6291 kg ha\(^{-1}\). P1 which was a combination of (100 kg ha\(^{-1}\) 23:21:0 +4S +50 kg ha\(^{-1}\) urea as basal and 100 kg ha\(^{-1}\) urea as top dressing ) was the second with 5422 kg ha\(^{-1}\) and lastly P3 which was a combination of 100 kg ha\(^{-1}\) 23:21:0 +4S 1 and 150kaha\(^{-1}\) urea as top dressing (4891 kg ha\(^{-1}\)). P2 gave highest yields because N was available at an early stage to the maize which made a good synchrony between the N demand by the maize crop and N supply from the urea P3 (the recommended practice in Malawi) resulted into lowest grain yield because it was too late for the plant to use the absorbed nitrogen for grain formation since it already had passed that critical stage where N use for grain formation is determined. As already indicated, urea fertilizer undergoes through a hydrolysis process to change to NO\(_3\) which can be taken up by the maize plant. This is in agreement with Arnon (1972) who indicated that a deficiency of N at a critical stage (i.e. the time the plants are about 20cm high) will cause a reduction in the number of rows of kennels per ear, thereby lowering the final yield. This effect cannot be overcome by an adequate supply of N at a later date.
Means in a column or row followed by the same letter are not significantly different.

Maize biomass yields under different fertilizer application practices during the 2003/04 crop season.

There was a significant interaction between the maize varieties and the fertilizer application practices (P<.001) on biomass yield (Table 2). In local maize, high biomass yield was under P2, followed by P3 and lastly PI. In Masika, high biomass yield was observed at P2 but there were no significant differences between PI and P3. While in DK8031, there was high biomass yield under P3 but there same yields for PI and P2. Highest biomass yields under P2 in Local maize and Masika may be attributed to the highest grain yield.

Table 1: Maize grain yields (kg/ha) under different fertilizer application practices during the 2003/04 growing season.

<table>
<thead>
<tr>
<th>Fertilizer practice</th>
<th>Grain Yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Local maize</td>
</tr>
<tr>
<td>PI</td>
<td>4646</td>
</tr>
<tr>
<td>P2</td>
<td>5369</td>
</tr>
<tr>
<td>P3&lt;sup&gt;1&lt;/sup&gt;</td>
<td>4454</td>
</tr>
<tr>
<td>Mean</td>
<td>4823&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>LSD</td>
<td>Maize varieties = 523.3 Fertilizer Practices = 473.1</td>
</tr>
</tbody>
</table>

Means in a column or row followed by the same letter are not significantly different.

Harvest indices for maize varieties under different fertilizer application practices during the 2003/04 growing season.

There was a significant interaction between the maize varieties and the fertilizer application practices (p<0.001 on biomass yield (Table 2). In local maize, high biomass yield was under P2, followed by P3 and lastly PI. In Masika, high biomass yield was observed at P2 but there were no significant differences between PI and P3. While in DK8031, there was high biomass yield under P3 but there same yields for PI and P2. Highest biomass yields under P2 in Local maize and Masika may be attributed to the highest grain yield.

Table 2: Biomass yield of maize varieties under different fertilizer application practices during the 2003/04 growing season.

<table>
<thead>
<tr>
<th>Fertilizer Practice</th>
<th>Biomass Yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Local</td>
</tr>
<tr>
<td>PI</td>
<td>12824&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>P2</td>
<td>15114&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>P3</td>
<td>13904&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>LSD</td>
<td>516.4</td>
</tr>
</tbody>
</table>

Means in a column followed by the same letters are not statistically different.

Harvest indices for maize varieties under different fertilizer application practices during the 2003/04 growing season.

There was a significant interaction between the maize varieties and the fertilizer application practices on harvest indices (p<0.001) (Table 3). P2 gave the highest harvest index in Masika and DK8031 of 0.49 and 0.51 respectively. This is so because the plants were able to take up the nitrogen from the urea fertilizer which was applied at an early stage and used it for grain formation. However, P1 and P2 gave the same harvest index of 0.40 in local maize. P3 gave the lowest harvest indices in all the maize varieties. This may be attributed to the fact that much of the urea which was applied late was not used efficiently in the formation of grain.
Table 3: Harvest indices for the maize varieties under different fertilizer application practices during the 2003/04 growing season.

<table>
<thead>
<tr>
<th>Fertilizer Practice</th>
<th>Harvest Index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Local</td>
</tr>
<tr>
<td>PI</td>
<td>0.40b</td>
</tr>
<tr>
<td>P2</td>
<td>0.40b</td>
</tr>
<tr>
<td>P3</td>
<td>0.32a</td>
</tr>
<tr>
<td>LSD = 0.018</td>
<td></td>
</tr>
</tbody>
</table>

Means in columns with the same letter are not significantly different.

**Cob height, plant height and 100 seed weight of maize under different fertilizer practices, 2003/04 crop season.**

Seed size was significantly different among the fertilizer application practices at P<0.001 (Table 4). P2 gave the highest 100 seed weight of 39.35g followed by PI (36.96g) and then P3 (34.92g). This implies that maize grain from P2 were bigger, and seed size an important factor for the farmers when selecting seeds for planting incase of local and composite maize varieties. However, fertilizer application practices had no effect on lodging, cob height and plant height.

However, the cob heights for maize varieties were significantly different at p<0.001 (Table 6).

**Table 4:** Effect of fertilizer practices on cob height, plant height and 100 seed weight of maize

<table>
<thead>
<tr>
<th>Fertilizer Practice</th>
<th>Cob height (cm)</th>
<th>Plant height (cm)</th>
<th>Lodging</th>
<th>100 seed weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI</td>
<td>115.5</td>
<td>177.7</td>
<td>2</td>
<td>36.96b</td>
</tr>
<tr>
<td>P2</td>
<td>113.6</td>
<td>175.0</td>
<td>2</td>
<td>39.35b</td>
</tr>
<tr>
<td>P3</td>
<td>115.5</td>
<td>172.6</td>
<td>2</td>
<td>34.92b</td>
</tr>
<tr>
<td>Mean</td>
<td>114.9</td>
<td>175.1</td>
<td>2</td>
<td>37.08</td>
</tr>
<tr>
<td>LSD</td>
<td></td>
<td></td>
<td></td>
<td>1.2</td>
</tr>
</tbody>
</table>

**Cob height, plant height and 100 seed weight of maize varieties**

There were significant differences among the maize varieties on 100 seed weight (P=0.012 ), cob height and plant height (P<0.001) (Table 5). DK8031 gave the highest 100 seed weight among the 3 varieties. The seed size for Masika and local maize was the same. Local maize had the highest cob height of 166.6 cm followed by DK8031 which had a cob height of 91.2 cm and Masika (86.9 cm). Local maize had the highest plant height of (245.3 cm) as compared to Masika and DK8031 which had (165.4 cm) and (175.1 cm) respectively. The differences in seed weight, cob height and plant height can be attributed to their genetic characteristics as indicated by Arnon, (1972) who stated that different cultivars grown under the same conditions may have differences in their performance due to genetic make up.

**Table 5:** Cob height, plant height and 100 seed weight of maize varieties

<table>
<thead>
<tr>
<th></th>
<th>Cob height (cm)</th>
<th>Plant height (cm)</th>
<th>Lodging score</th>
<th>100 seed weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local</td>
<td>166.6b</td>
<td>245.3b</td>
<td>2</td>
<td>35.17b</td>
</tr>
<tr>
<td>Masika</td>
<td>86.9b</td>
<td>169.4b</td>
<td>3</td>
<td>34.60b</td>
</tr>
<tr>
<td>Hybrid</td>
<td>91.2b</td>
<td>175.1b</td>
<td>2</td>
<td>41.45b</td>
</tr>
<tr>
<td>LSD</td>
<td>13.14</td>
<td>15.24</td>
<td></td>
<td>3.7</td>
</tr>
</tbody>
</table>

Means in a column or row followed by the same letters are not significantly different.
CONCLUSION AND RECOMMENDATIONS

The results from this study have demonstrated that highest maize yields were realized with application of 100kgs of 23:21:0 +4S + 75kg urea as basal and then 75 kg urea as top dressing (P2) as compared to PI (100 kha⁻¹ S n +4S +50 kg ha⁻¹ urea as basal and 150kg ha⁻¹ urea as top dressing) and P3 (100 k2 ha⁻¹ 23-21-0 +4S basal and 150 ha⁻¹ urea as top dressing). DK8031 yielded highest (6313kg/ha) as compared to Masika (5467kg/ha) and local maize (4323kg/ha). In addition to composites and local maize, farmers should be encouraged to grow hybrid varieties because they are more efficient in utilizing the available nitrogen. Therefore farmers in areas with similar ecological conditions as Bunda should be encouraged to apply half of the urea dose as part of basal fertilizer and the other half as top dressing in maize to increase production. These findings are from one growing season and therefore further studies should be conducted in order to have conclusive results.

Acknowledgement

We are grateful to Bunda College of Agriculture for funding this research.
REFERENCES


APPENDIX

Fig 1:

Average monthly rainfall at Bunda from November 2003 to April 2004, 2003/04 growing season.

I □ Seriesi