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Banana irrigation management and optimization: A comparative study of researcher-managed and farmer-managed irrigated banana production in Shire Valley, Malawi

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Banana yield and quality in Malawi is low due to drought, low fertility and poor management practices. Therefore, a comparative researcher-managed and farmer-managed irrigated banana study was initiated in 2004/2005 to develop guidelines and promote banana irrigation optimisation for small-scale farmers. Specifically, the research aimed to determine and compare researcher-managed and farmer-managed optimum irrigation in respect to banana yield, quality, income and gross margins, and facilitate transfer of banana irrigation technology to farmers. Irrigation treatments ranged from 0, 50 and 100% evapotranspiration (ET) of estimated banana ET, laid out in a randomized complete block design (RCBD) with four replicates. Irrigation was scheduled using the soil moisture balance system. The results of banana production and gross margin analysis for both researcher-managed and farmer-managed experiments showed that average yield and quality increased linearly with increasing irrigation. Highly significant differences (P < 0.001) were observed between amounts of applied water in average bunch weight, average hand weight and average finger weight per hectare both under researcher-managed and farmer-managed fields, respectively. The gross margin analysis showed negative gross margin under non-irrigated banana enterprise and positive gross margin at 100% ET for both researcher-and farmer-managed fields, respectively. Irrigation raised farmer earnings from -4 to 27 US$/day (non-irrigated to irrigated banana) and it was optimal to produce banana under 100% ET. The findings showed that banana enterprise has a commercial orientation that can reduce poverty for smallholder farmers. It is recommendable that Malawi and other countries should advocate banana irrigation agribusiness because it can facilitate the attainment of food security and poverty reduction.

Key words: Irrigation scheduling, evapotranspiration, gross margin, banana.

INTRODUCTION

Banana (Musa spp) is both a staple food and cash crop in Malawi. The main production districts are Karonga and Chitipa where banana is a staple food (Chizala, 1995). Thyolo, Mulanje and Nkhotakata districts, among others, grow banana as a cash crop at small-scale level (Figure 1). IITA (2004) survey conducted in Nkhatata-Bay and
Mulanje found that 50% of the income to farmers in Nkhata-Bay comes from banana, while in Mulanje banana contributes 43% of the farmers' income. The survey also found that banana was the second most important crop in Nkhata-Bay after cassava, while in Mulanje banana was the third most important crop after maize and cassava. But banana yields and quality have been low and poor to effectively influence poverty and hunger eradication due to drought, poor soil fertility, pests and diseases, low yield varieties (Banda and Mwenbanda, 1992) and lack of information on recommendable management practices. Giant (Williams) and Dwarf Cavendish are some of the high yielding varieties (Banda and Mwenbanda, 1992) among desert bananas that are highly promoted in Malawi. The Ministry of Agriculture and Food Security has been promoting banana farming through production of health planting materials and training farmers on proper husbandry practices in Shire Valley since 1997. Other Cavendish promoted includes Grand nain, Gros Michel and Chinese Cavendish.

Banana is such a promising miracle (Wambugu, 2004) crop with a potential to eradicate hunger and poverty in Africa in general since it is not a seasonal crop; it is very nutritious (potassium, vitamin A) and has multiple dietary uses such as desert, beer brewing, and fruit juice as well as medicinal use. Its low resistance to drought and rapid physiological response to soil water deficit (Robinson, 1995) make it sensitive to even slight variation in soil water content (Robinson and Alberts, 1987). This is because of its poor ability to draw water from dry soil due to shallow spreading root distribution (Champion, 1968). Goenaga and Irizarry (2000) reported a banana decrease from 47 to 9% or visa vice due to imposed drought stress. Banana as tropical crops requires 1200 to 2690 mm of water depending on the prevailing climate (Simmonds as cited by Robinson and Alberts, 1986; Doreenbos and Kassam, 1986). Such amount is not attained in Shire Valley with annual rainfall less than 600 mm (Fandika et al., 2007). Apart from drought, the exact nature of banana as biological factor in banana production (Robinson, 1995). High yield of 60 t ha\(^{-1}\) year\(^{-1}\) (Fandika et al., 2006) has been reported in Shire Valley, Malawi when irrigated at 100% ET. Despite promising banana yields from previous conversional irrigation research, yields and quality among farmers were still low and poor. Majority of farmers are still growing banana under unimproved techniques because were not involved in previous conversional irrigation research. Conversional research lack farmer's participation in technology development and such approach reduces dissemination and adoption rate by small-scale farmers (Donovan, 1994; Pretty, 1995).

In the Shire Valley of Southern Malawi, banana production is mainly practiced under rainfed conditions. In this semi-arid zone, high solar radiation (>17.0 MJm\(^{-2}\)d\(^{-1}\)), warm temperatures (24.1 to 36.5°C), and low relative humidity (61 to 77.5%) make continuous banana harvesting over the whole year impossible (Fandika et al., 2006). Adequate water requirements can only be met by irrigation as consequences of low and erratic rainfall (400 to 600 mm) falling in a season that range from October to March. Nevertheless, useful information about banana irrigation and optimization, obtained from Kasinthula Research Station (Fandika et al., 2006), International Research Station (Goenaga and Irizarry, 2000) and other fruit crop growing areas (Banda and Mweneneb, 1992) was not fully adopted by small-scale farmers in Shire Valley region. Goenaga and Irizarry (1998) recommended 1.0 pan factor (100% ET) as the adequate water consumption for banana optimum production (Doreenbos and Kassam, 1986). Hence, the comparative case study of researcher-managed and farmer-managed banana experimentation on banana irrigation management was initiated for comparison of conversional research findings with lead farmer’s findings so that farmers’ capacity to improved technologies is assessed. The purpose of the study was to develop guidelines and promote banana irrigation optimization for small-scale farmer poverty and hunger eradication.

Specifically, the study aimed at determining and comparing researcher-managed and farmer-managed optimum irrigation in respect to banana yield, quality, income and gross margins, and facilitate transfer of effective irrigation treatments to small-scale farmers through lead farmers in Malawi.

**MATERIALS AND METHODS**

**Location**

The comparative researcher-managed and farmer-managed banana irrigation optimization study was conducted at Kasinthula Research Station in Chikwawa, Malawi. It is located at a latitude of
Figure 1. Map of Malawi showing the towns and Districts.

16° S and longitude 34°5' E. The altitude is 70 m above sea level whose long-term annual average minimum and maximum temperature, annual precipitation, relative humidity, wind speed and evaporation are 18.6°C, 35.6°C, 520 mm, 70%, 4.7 km day⁻¹ and
8.6 mm day⁻¹, respectively. Scientific experimentation and unit farming system approaches (Chambers et al., 1989) were concurrently used to easily compare researcher-managed and farmer-managed banana yields, quality and gross margins in 2004/2005 growing seasons.

**Unit farming research system**

Unit farming research system is a technology transfer initiative (Chambers et al. 1989; Donovan 1994) for communities around the research station. In this case, new irrigation technologies developed by the Department of Agricultural Research Services at Kasinthula Research Station in Chikawawa were utilized by farming communities including farmers who reside around the research station thus Technology Transfer Initiatives around Kasinthula Research Station. The station embarked on this Technology Transfer Initiative in August, 2002 as a response to the concern of low adoption of irrigation management and optimization technologies by communities surrounding the research station. The Technology Transfer Initiative at Kasinthula Research Station was different from other research stations in the sense that, the lead farmers were selected from their homes to practice new farming technologies on station, while at other research stations, lead farmers were left at their original farms to practice new developed technologies. The selected lead farmers were called unit farmers and the system is called unit farming system and was used to acquaint farmers with modern irrigation system before the technology is fully transferred to local farmer's fields.

Three farmers were participatory selected (by research scientists/extension officers) from a sample of more than 3000 farm families of Chikawawa District Agriculture Office within Shire Valley Agricultural Development Division (SVADD). Research scientists from Kasinthula Research Station linked with the District Agricultural Development Officer (DADO) to come up with farmers who could practice new technology under research-farmer management. The three lead farmers (namely Christopher Makhaza, Eliya Zeti and Yohane Tembo) were selected from Mitole Extension Planning Area (EPA). Each farmer had a different crop of Makhaza, Eliya Zeti and Yohane Tembo) were selected from Mitole management. The three lead farmers (namely Christopher

**Experimental design**

Both researcher-managed and farmer-managed approaches used three irrigation treatments of 0, 50 and 100% ET. The amount of applied water was determined from the calculated banana ET. The calculated ET (100% ET) from weather data was treated as a base amount. Then the other amounts were calculated as percentages of the base amount in the order of 0 and 50%. The treatments were laid out in a randomized completely block design (RCBD) with four replicates. The plot sizes were 10 × 10 m with 4 mats spaced 2.5 × 2.5 m totaling to 16 mats per plot which is equivalent to 1600 mats per hectare. The same irrigation regimes were deliberately tested at two fields to convince the farmers that they can deal with the effects of drought stress on banana production. The study was comparing yields, quality and gross margin at lead farmer level with those from research-managed field to show other farmers that it is possible for them to adopt such technology and achieve high yields and gross margins.

**Agronomic practices**

The land was ploughed by tractor and 10 × 10 m basins were hand made. Banana suckers (variety Giant Williams) were planted on 3rd February, 2004 in pits at a spacing of 2.5 × 2.5 m equivalent to 1600 suckers per hectare. Cattle manure was first applied at 10 kg per planting hole. Irrigation water was applied uniformly until the plants were fully established. Irrigation water was applied in 10 × 10 m basins using a gated 15 cm diameter Poly(Vinyl Chloride) (PVC) pipe. Each gate was set at a flow of 30 L/min. The flow rate out of each gate was determined using a bucket method. The PVC was laid at the beginning of the furrows and was connected to a concrete lined canal in which the water level was maintained at a constant head above the centre of the PVC pipe inlet. Irrigation scheduling under both fields (Researcher-managed and farmer-managed fields) was carried out by maintaining a soil moisture balance sheet. The soil moisture storage was estimated from the available water holding capacity of 100 mm m⁻³ and the crop root zone. 200 kg N ha⁻¹ and 200 kg K ha⁻¹ fertilizer was applied to both fields. The cost of farm inputs and labour was recorded for gross margin analysis.

**Field day, farmers training and data collection**

Field days and farm visits were being conducted for farming communities to learn technologies being implemented by the unit farmer and appreciate how improved technologies can eradicate hunger and poverty at household and national level in Malawi. The Department of Research trained the unit farmer in all the banana production techniques which he was explaining to other farmers during field days, open days and visits by other farmers. The lead farmer was explaining on how he implemented the research program, yield and profits being realised from the project. The unit farmer finally graduated to his own farm after government loaned him a 20 horse power pump to establish his own field outside the research station.

During harvest of the banana, research personnel collected data on yield and other desirable yield components which were analyzed accordingly using analysis of variance (ANOVA) to determine the yield and profit variability between researcher-managed and farmer-managed fields. Regression analysis was used to determine the relationship between yield and water application. It was envisaged that through data collection, one can know why and how science and technology benefit or fail to benefit the resource-poor Malawian farmers.

**RESULTS AND DISCUSSION**

The results showed that average yields (hand weight, bunch weight and average yield per hectare) and gross margin increased linearly with increasing amounts of applied water (Tables 1 to 4) both under researcher-managed and farmer-managed banana fields. Highly significant differences (P < 0.001) were observed between amounts of applied water in average bunch weight, average hand weight and average banana yield per hectare (Table 1). Highest bunch weight of 20.5 and 18.86 kg for researcher-and farmer-managed fields, respectively was obtained at 100% ET of applied water, while the 0% irrigation treatment had the lowest bunch weight of 5 and 3.46 kg for researcher-and farmer-managed fields, respectively (Tables 1 to 2). Hand weight
Table 1. Banana variable response to different amount of applied water under researcher-managed fields.

<table>
<thead>
<tr>
<th>ET (%)</th>
<th>Applied water</th>
<th>Days to flowering</th>
<th>Days to harvest</th>
<th>Number of hands per bunch</th>
<th>Number of fingers per hand</th>
<th>Hand weight (kg)</th>
<th>Average bunch weight (kg)</th>
<th>Banana yield (t ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>609</td>
<td>342</td>
<td>478</td>
<td>7</td>
<td>14</td>
<td>0.59</td>
<td>5.0</td>
<td>3.45</td>
</tr>
<tr>
<td>50</td>
<td>980</td>
<td>316</td>
<td>412</td>
<td>8</td>
<td>15</td>
<td>2.09</td>
<td>17.3</td>
<td>21.31</td>
</tr>
<tr>
<td>100</td>
<td>1722</td>
<td>307</td>
<td>409</td>
<td>9</td>
<td>15</td>
<td>2.39</td>
<td>20.5</td>
<td>25.84</td>
</tr>
<tr>
<td>Mean</td>
<td>322</td>
<td>433</td>
<td>8</td>
<td>15</td>
<td>1.69</td>
<td>14.3</td>
<td>16.87</td>
<td></td>
</tr>
<tr>
<td>SE±</td>
<td>14.60</td>
<td>16.92</td>
<td>0.42</td>
<td>0.49</td>
<td>0.16</td>
<td>1.56</td>
<td>2.67</td>
<td></td>
</tr>
<tr>
<td>CV%</td>
<td>10.33</td>
<td>8.97</td>
<td>11.86</td>
<td>7.7</td>
<td>21.18</td>
<td>25.01</td>
<td>29.40</td>
<td></td>
</tr>
<tr>
<td>Significance</td>
<td>NS</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
</tbody>
</table>

Note: P < 0.05 = *; 0.01 = **; 0.001 = ***.

Table 2. Banana variable response to different amount of applied water under farmer-managed conditions.

<table>
<thead>
<tr>
<th>ET (%)</th>
<th>Applied water</th>
<th>Days to flowering</th>
<th>Days to harvest</th>
<th>Number of hands per bunch</th>
<th>Number of fingers per hand</th>
<th>Hand weight (kg)</th>
<th>Average bunch weight (kg)</th>
<th>Banana yield finger weight (t ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>609</td>
<td>345</td>
<td>470</td>
<td>4.8</td>
<td>10.0</td>
<td>0.51</td>
<td>3.5</td>
<td>1.20</td>
</tr>
<tr>
<td>50</td>
<td>980</td>
<td>310</td>
<td>412</td>
<td>7.6</td>
<td>14.0</td>
<td>2.32</td>
<td>16.3</td>
<td>20.31</td>
</tr>
<tr>
<td>100</td>
<td>1722</td>
<td>306</td>
<td>410</td>
<td>7.6</td>
<td>14.2</td>
<td>2.37</td>
<td>18.9</td>
<td>21.40</td>
</tr>
<tr>
<td>Mean</td>
<td>320</td>
<td>431</td>
<td>6.7</td>
<td>12.7</td>
<td>1.73</td>
<td>12.9</td>
<td>14.30</td>
<td></td>
</tr>
<tr>
<td>SE±</td>
<td>14.60</td>
<td>16.92</td>
<td>0.42</td>
<td>0.49</td>
<td>0.16</td>
<td>1.56</td>
<td>2.67</td>
<td></td>
</tr>
<tr>
<td>CV%</td>
<td>10.33</td>
<td>8.97</td>
<td>11.86</td>
<td>7.7</td>
<td>29.55</td>
<td>27.99</td>
<td>36.48</td>
<td></td>
</tr>
<tr>
<td>Significance</td>
<td>NS</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
</tbody>
</table>

Note: P < 0.05 = *; 0.01 = **; 0.001 = ***.

Table 3. Banana gross margin analysis under researcher-managed field conditions.

<table>
<thead>
<tr>
<th>ET (%)</th>
<th>Irrigation (mm)</th>
<th>Yield (tha⁻¹)</th>
<th>Banana Suckers</th>
<th>Banana price (US/kg)</th>
<th>Sucker price (US/seed)</th>
<th>Income (US)</th>
<th>Irrigation cost (US$50/interval)</th>
<th>Farm input costs (US$)</th>
<th>Total costs (US$)</th>
<th>Gross margin (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>3.15</td>
<td>1000</td>
<td>0.32</td>
<td>1.07</td>
<td>2,078.00</td>
<td>0</td>
<td>3528.5</td>
<td>3528.50</td>
<td>-1,450.50</td>
</tr>
<tr>
<td>50</td>
<td>980</td>
<td>21.31</td>
<td>6500</td>
<td>0.32</td>
<td>1.07</td>
<td>13,774.2</td>
<td>1960</td>
<td>3528.5</td>
<td>5488.50</td>
<td>8,286.70</td>
</tr>
<tr>
<td>100</td>
<td>1722</td>
<td>25.84</td>
<td>8200</td>
<td>0.32</td>
<td>1.07</td>
<td>17,042.8</td>
<td>3444</td>
<td>3528.5</td>
<td>6972.50</td>
<td>10,070.3</td>
</tr>
<tr>
<td>Mean</td>
<td>1554</td>
<td>16.77</td>
<td>5233</td>
<td>0.20</td>
<td>1.07</td>
<td>10,965.0</td>
<td>2702</td>
<td>3528.5</td>
<td>5329.83</td>
<td>8,452.60</td>
</tr>
</tbody>
</table>

The number of fingers per hand resulted into significant differences that followed similar trend as bunch weight, and it was hand weight per bunch significant differences that resulted into significant differences in both bunch and total banana yield. Similarly, highest average banana yield of 25.84 and 21.4tha⁻¹ for research and farmer, respectively.
were obtained at 100% ET of applied water. The 0% irrigation treatment produced the lowest average banana yield of 3.45 and 1.20 t ha⁻¹ (Tables 1 to 2) under researcher-managed and farmer-managed fields, respectively. The yields under researcher-managed was higher than under farmer-managed banana though not significantly different (P > 0.05). These results agrees with other findings (Robinson and Alberts, 1986; Manica et al., 1976) who found that increasing water application from 25 to 75% ET increases bunch weight and annual yields and Geonaga and Irizarry (1998) who stated that water for banana is applied sufficiently at a pan factor of 1.0 which is equivalent to 100% ET in is study. However, the total amount of water the banana used including rainfall ranged from 609 to 1722 mm which is within the range documented by Doreenbos and Kassam (1986).

The banana yield results between researcher-managed and farmer-managed fields were not significantly different showing that small-scale farmers can adopt scientific standards if properly trained or oriented. Furthermore, these yields trends showed other farmers that banana requires ample and frequent supply of water (Fandika et al., 2006) and that because water deficits in the vegetative period affect leaf development which in turn can influence the reproductive phase in the number of flowers, hands and bunches produced (Wahad, 2000). However, it was interesting to note that average number of hands per bunch and average number of fingers per hand (Tables 1 to 2) did not significantly differ with increasing amounts of applied water entailing that these factors are not influenced by soil water content but are perhaps genetically determined. But day to harvesting was different because day to flowering was reduced by water deficit while reducing yield.

During open days, farmers observed and learnt that water deficits in the yield formation period reduce fruit size, quality and suckers production. They also noted that reduced leaf area reduces the rate of fruit filling resulting in small fruit diameters in low water application treatments. Lead farmers also observed significant differences between plant characteristics such as neck length, average plant height, days to harvest, average bunch diameter and average pseudo-stem showing that water is very essential for a healthy banana plant and that water constitutes a major portion of a banana plant to as high as 90% (Chizala, 1995). The greatest lesson to farmers was that regular water supply under irrigation, produces taller plants with greater leaf area which results in earlier shooting, higher yields as well as high profits. Both researcher-managed and farmer-managed banana fruits were sold at US$0.32 per kg at supermarkets while seed was sold at US$1.07 to Non-Governmental Organizations (NGOs), government institutions and other individual farmers.

Irrigated banana is of high quality and offers an agricultural enterprise to small-scale farmer which is market-orientated as it fetched high gross margin than non-irrigated banana. Robinson and Alberts, (1987) reported increased quality and premium market prices on irrigated banana. As of now, the number of farmers that has adopted banana irrigation management and optimization on commercial basis in their fields has increased from one to more than twenty in communities around Kasinthula Research Station. In addition, NGOs have influenced the adoption in their impact areas. As a result more than 100,000 banana suckers (seed) from Kasinthula were sold to other regions of the country. The gross margin analysis showed negative gross margin under non-irrigated banana enterprise (-US$1450.50 and -US$2192.2) and positive gross margin (US$10,070.30, and US$9,933.50) at 100% ET for researcher-managed and farmer-managed fields, respectively. Irrigation raised farmer earnings from -US$4 to US$27 per day (non-irrigated to irrigated banana) and it was optimal to produce banana under supplementary irrigation (100% ET) other than non-irrigated and full irrigation (Tables 3 to 4). The findings showed that banana enterprise has a commercial orientation that can reduce poverty for smallholder farmers in Malawi. Agricultural sectors can use such a miracle promising crop and technology to further carry a market oriented agribusiness study for banana to
enhance attainment of Millennium Development Goals (MDGs) in the sub-Saharan Africa.

The scientists and extension workers can properly guide farmers in crop diversification and on how to reduce risk and uncertainties in times of market fluctuation and yield drop. It is believed that banana is one such crop in the sub-Saharan Africa that will facilitate the achievement of food security and poverty reduction. The main reasons why banana can help to achieve MDGs are that banana has multiple dietary uses and is not a seasonal crop which is thus harvested all year long (Wambugu, 2004). If properly managed, therefore, farmers will have food and income all year long. Sub-Saharan Africa should take it as its miracle crop for poverty and hunger eradication.

CONCLUSIONS AND RECOMMENDATIONS

Irrigation, technology dissemination and farmer participatory research improved banana yield and quality. The farming research system facilitated development of banana production guidelines in Malawi. The yield and gross margin analysis is under non-irrigated banana (-U$1450.50 and -U$2192.2) and positive (U$10,070.30, and U$9,933.50) at 100% ET irrigation for researcher-managed and farmer-managed fields, respectively. Irrigation raised farmer earnings from -U$4 to U$27 per day (non-irrigated to irrigated banana). It is optimal and profitable to produce banana under supplementary irrigation (100% ET) other than non-irrigated. Unit farming research system increased tranfering of this technology to a wide range of farmers. It can therefore be concluded that banana production among small-scale farmers can be optimized for food security and income at household level through farmer’s participation. If optimal banana production at small-scale irrigation farms promoted in Malawi, food security and income per capital will rise. The findings showed that banana enterprise has a commercial orientation that can reduce poverty for smallholder farmers. It is, therefore, recommendable that nations should advocate banana irrigation agribusiness.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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