AFRICA UNIVERSITY
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AN EVALUATION OF EFFICACY AND COST EFFECTIVENESS OF WEED CONTROL OPTIONS IN SUGARCANE PRODUCTION AT MAFAMBISSE ESTATE IN MOZAMBQUE

BY

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ABSTRACT

Field trials were conducted at Mafambisse Sugar Estate in Sofala Province of Mozambique to evaluate the efficacy and cost effectiveness of weed control options in sugarcane production. Two sites were set up one under flood irrigation and the other under sprinkler irrigation. Four sugarcane varieties were planted in June 2012 at each site with plots placed in a completely randomised design with four treatments and four replicates of each treatment in a specific variety. The seed rate of 10 tons/ha was used in plant cane and basal fertilizer Monoammonium Phosphate (MAP) at a rate of 318 kgs/ha (N11-P22-K00) was applied. Top dressing using Urea fertilizer was applied at 12 WAP at a rate of 250 kgs/ha (N115 kgs/ha). Pre-emergent herbicides were applied to the plots that were supposed to be applied. For plant cane, Pendimethalin 500 EC at 3.5 l/ha, Extreme plus at 1.2kg/ha and MCPA 750 SL at 3 l/ha using manually. Post emergent herbicide was applied using Harness Extra at 2.8 l/ha, Ametryn 500 SC at 4 l/ha and Gramoxone 30 EC at 1 l/ha. Pre-emergent herbicides were applied to the ratoon cane, Pendimethalin 500 EC at 3.5 l/ha, Extreme Plus at 1.2 kgs/ha and Hexazinone 240 SL at 1.5 l/ha and post emergent herbicide application Tebusan 500 SC at 1.5 l/ha, Diuron 80 at 2.5 l/ha and Foliwet 900 at 0.6 l/ha. The best yield of 72 t/ha was obtained in N21 variety in sprinkler irrigated plant cane in the combination treatment. Hoeing treatment of N21 in furrow irrigation plant cane obtained the highest yield of 80.28 t/ha. In ratoon cane, best yields and profit margins were obtained in the N21 variety in the herbicide treatment. In conclusion, N21 variety is well adapted to Mafambisse conditions and a combination of herbicide and hand weeding to be recommended.

Key words: sugarcane, weed management, cost effectiveness, yield, profit margin.

DECLARATION

I declare that this dissertation is my original work except where sources have been cited and acknowledged. The work has never been submitted nor will it ever be submitted to another University for the award of a degree.

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DEDICATION

This work is dedicated to my family, my wife Privilege and my sons Fidel Tendai, Liberty Tinashe, Trevor Emanuel Tinaye and my lovely daughter Bethel Rutendo Muzamani.

LIST OF ACRONYMS AND ABREVIATIONS

CEPAGRI	Centro de Promoção de Agricultura (Centre of Promotion in Agriculture)
DAC	Days after cut
DAP	Days after planting
GAIN	Global Alliance for Improved Nutrition
IAA	Indole Acetic Acid
kgN/ha	kilograms of nitrogen per hectare
l/ha	Litres per hectare
Mandays	Man hours per day
PPI	Pre plant incorporated
WAP	Weeks after planting
t/ha	Tons of sugarcane per hectare
SHE	Safety Health and Environment

DEFINITION OF KEY TERMS

BRIX- The term used when a refractometer equipped with a scale, based on the relationship between refractive indices at 20 ^{0}c and the percentage by mass of total soluble solids of a pure aqueous sucrose solution.

FIBRE- The water insoluble matter of cane and bagasse from which the brix free water has been removed by drying.

PLANT CANE- The crop of sugarcane established through planting of cane sticks as seed.

POL %- The apparent sucrose content of any substance expressed as a percentage by mass and determined by the single or direct polarisation method.

RATOON CANE - The crop of sugarcane established through tillering of the previous roots of sugarcane.

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CHAPTER 1

INTRODUCTION

1.1 Back ground of sugarcane production in Mozambique

Agriculture remains the back bone of the Mozambican economy with its contribution of 31.5% of the Gross Domestic Product (CEPAGRI, 2009). Agriculture in Mozambique creates employment to more than 80% of its total population and provides livelihood to the majority of 25 million people (CEPAGRI, 2009).

Sugarcane production plays an important role in economic growth and employment creation of the country. There are four operational sugar mills in the country and these employ over 30 000 people in the national labour force (CEPAGRI, 2009). 25 000 employees are involved in the actual production and the 5000 are involved in the transportation of raw materials and end products of the industry. Sugarcane production is being threatened by ever escalating costs of production as well as the ever dropping of world sugar prices and hence the viability of the industry. The viability of the sugar industry is determined through the difference between the costs incurred in the actual production of sugarcane together with the milling costs to produce sugar and the total revenue. Pest control is one of the major costs incurred in sugarcane production, in particular weed management aspect (Sundara, 1998).

The costs involved in weed management ranges from acquisition of equipment for weed management, the cost of chemicals, labour costs, protective clothing for herbicide application, salaries and wages for herbicide applicators and the actual insurance of the employees as well as the possible accidents that are incurred in the weed control practice that can prove to be costly as compensation to employees in case of accidents (Gupta, 2000).

A proper weed management system has to be adopted that is cost sensitive, and as well control effective to manage the weeds below the economic injury level. Weeds are known to cause yield losses up to 70 % and can even be higher if left unattended. They also lead to quality loss of the product and even create breakdowns to the mill if they are hauled together with cane to the mill for crushing (Sundara, 1998).

Weeds are known to harbour insect pests and diseases that will directly or indirectly affect the crop performance in the field which eventually impacts on yield.

1.2 Cost drivers in sugarcane production at Mafambisse Sugar Estate

Based on the budget figures for the 2013-14 production season and the subsequent year, the cost drivers at the estate were analysed and the figure below shows the contribution of each driver in relation to the total cost of production. The global cost of production was at US$0.76/kg and the analysis was ranked highest in relation to the global costs.

Drivers of high costs in sugarcane production incudes personnel costs, haulage costs, fertilizers, land preparation maintenance costs, chemicals and diesel as shown in figure 1.

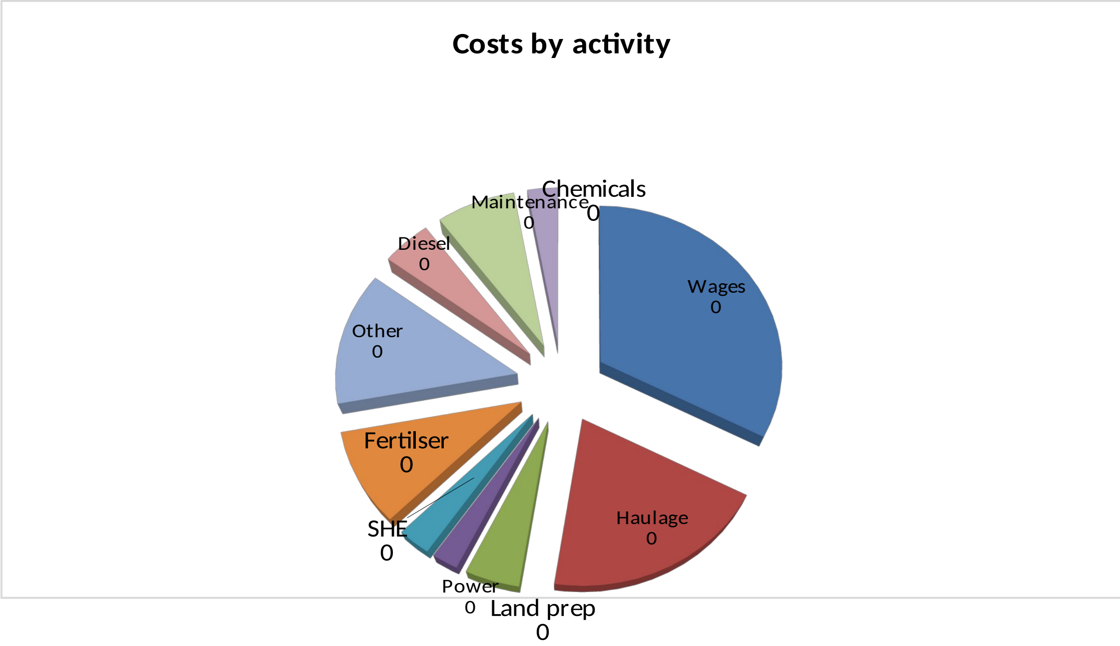

Figure 1: Cost drivers by activity in sugarcane production (Annual report for Tongaat Hulett Sugar, Mafambisse Estate, 2015)

1.3 Justification for the study

Sugarcane production like any other business is done to maximise profits. This can only be achieved through adoption of best production practices that reduces the costs and increase production. Weed pressure has proved to be one of the major contributing factors in yield reduction of sugarcane at Mafambisse estate.

Due to continued drop in world sugar price on the world market, the viability of the sugar industry is threatened and hence the need to find the most effective option and most efficacious weed control system as a way of cutting costs so that the viability of the industry is guaranteed.

In many operations, there is duplication of activities where by a full herbicide programme is followed at the same time employing a full mechanical weeding programme resulting in increased costs and eventually reducing the profit margins.

Mafambisse Estate is located on the flood plains of the Pungwe River, with very heavy basaltic clays ranging from 40 to 80% clay and a very high water table (IIAM, 2013). The effective rooting depth ranges from 0 to 40 cm (IIAM, 2013). As a result, the crop tends to grow very slow due to these limiting factors which in turn give the weeds a competitive advantage over the crop before the canopy. The predominant weeds are the *Rottboelia* sp, *Cyperus* sp, *Cynodon dactylon*, *Pannicum* sp,, *Commelina benghalensis* and the *Ipomoea* sp.

With the type of weeds predominant at the Estate, much of them require specific weed control method and not suitable to other forms of weed management due to their complexity in their growth characteristics. As a result of this, there is a need to come up with the best weed control action that can deal with the weed pressure at the estate. By looking at the Sugar estates in Mozambique, all of them are located along the flood plains of major rivers in the country and hence the type of challenges encountered in weed management programmes are tentatively similar and hence the usefulness of the study to the sugar industry.

1.4 Statement of the problem.

Weeds are a big problem in sugarcane production industry. Sugarcane is a perennial crop and as a result, the increased interaction of the crop with the weeds can lead to problems in the implementation of the weed management options especially the perennial weeds. Weeds compete for growth resources such as sunlight, moisture, nutrients and carbon dioxide and if unchecked weeds can lead to yield losses up to 70 % (Aldrich and Kremer, 1997). Weeds affect the quality of the crop at harvesting as they can be mixed with the crop during loading leading to poor crop quality being supplied to the mill and this can even lead to rejection of the crop. The presence of weeds in loaded cane to the mill for crushing can lead to discolouration of the actual sugar and an increase in the fibre content which is not required in sugarcane processing. Weeds also increase the cost of production by hindering work process and hence lead to decreased productivity by workers (Blackburn, 1984).

Weeds harbour insect pests and diseases which increase the crop attack by pests and disease, eventually resulting in decrease in yield of the crop and hence a negative influence in enterprise productivity and profitability (Anderson, 1996). This is because of increased costs of pest control and lower quality of the crop since there will be more damaged cane stalks in the harvested crop and hence reduced sucrose levels.

Objectives of the study

1.5.1 Main objective

To evaluate the efficacy and cost effectiveness of weed control options in sugarcane production.

1.5.2 Specific objectives

(i) To determine the effectiveness of chemical weed control, manual weed control and a combination of chemical and manual weed control on yield of sugarcane.

(ii) To compare the profit margins of chemical weed control, manual weed control and a combination of chemical and manual weed control systems.

(iii) To determine the most effective and cost effective weed control options on both plant cane and ratoon cane.

1.6 Research Questions

(i) What are the effects of chemical weed control, manual weed control and a combination of chemical and manual weed control on growth of sugarcane?

(ii) What are the effects of chemical weed control, manual weed control and a combination of chemical and manual weed control on yield of sugarcane?

(iii) What are the effects of chemical weed control, manual weed control and combination of chemical and manual weed control on cane quality?

CHAPTER 2

REVIEW OF RELATED LITERATURE

2.1 Sugarcane production in Mozambique

Sugarcane (*Sacharum officinarum* L.*)* belongs to the grass family. Production of sugarcane in Mozambique dates back to the colonial era when it was brought in by the Portuguese for chewing purposes. After independence in 1975, there was an exodus of trained personnel and hence the production nearly came to a halt. Renewed production of sugarcane started in early 2000 after some 16 years of civil war with arrival of foreign companies to revive the shutdown sugar mills due to civil war (Zacarias and Esterhuizen, 2013). From the year 2000 to date, sugarcane production is showing a steady increase due to political and economic stability which is attracting a lot of investments and opening of sugar consuming industries and hence the increase in demand.

The production of sugarcane in Mozambique was projected to rise, leading to increased sugar production. Initially, the sugar produced was for local consumption only but with the increased production in the early 2000, 60% of the annual production now reaches the European markets after the Economic Partnership Agreement (E.P.A) between the Mozambican Government and European Union markets (Zacarias and Esterhuizen , 2013; CEPAGIR, 2009).

2.2 Trends of sugarcane production in Mozambique

At the end of 16 years of civil war in the early 1990s, the Mozambican Government ventured into the rehabilitation and modernization drive of the sugar industry. In 1992, with the rehabilitation and modernization of the industry the area planted to sugarcane was 40 000 ha in the 1992/93 season (Zacarias and Esterhuizen, 2013). The area increased to 45 000 ha in the 2012/13 season with sugar production increasing from 151 000 tons sugar in 1992/93 season to 410 604 tons sugar in 2012/13 season (Zacarias and Esterhuizen , 2013).

2.3 Trends of sugarcane production at Mafambisse Estate

Sugarcane production at Mafambisse sugar estate dates back to 1969. The first fields to be opened up for sugarcane production were made available in 1969 and the first crushing was witnessed 3 years later. The sugarcane production in 1970 was 349 311.6 tons of raw cane and sugar production was 39 743.5 tons. Ten years later Mafambisse produced 418 928.16 tons of raw sugarcane which was crushed to produce 45 339.3 tons of sugar. The production dropped to 126 507.81 tons of raw sugarcane in 1990 and only 13 080.96 tons of sugar were made on the same piece of land. This was mainly attributed to the civil unrest that lasted for 16 years from 1975 to 1992. The year 1992 was the most affected because it was almost at the peak of economic meltdown from the effects of civil unrest (Zacarias and Esterhuizen , 2013).

In the year 2000, after the civil unrest, with investors coming into the country, Tongaat Hulett Sugar Company took over the management of the company and the yields started to go up and a total of 293 280.34 tons of sugarcane was produced to make a total of 31 081.66 tons of sugar. In 2010, a total of 454 248 tons of sugarcane were produced and a total of 44 669 tons of sugar were made. Some expansion projects were embarked on and an increase in area under sugarcane was realised with a total of 3000 ha further up the estate were established and total tons in 2013/14 season came up to 557864.22 tons of sugarcane and 65 251 tons of sugar were made.

2.4 Challenges in sugarcane production in Mozambique

Mozambique has a comparative advantage in sugarcane production industry due to its favourable natural resources such as good quality soils, regular rainfall and favourable conditions (CEPAGRI, 2009).However, the yield of sugarcane in Mozambique remains below average (Zacarias and Esterhuizen, 2013). The yield loses in sugarcane production could be attributed to various factors involved in actual production. Weed pressure is one of the contributing factors to lower yields in sugarcane production. Losses due to weeds in the range of 40-70% in yield of sugarcane have been recorded due to unchecked growth of weeds (Solomon *et a*l, 2000). Control of weeds in sugarcane production can either be chemical, mechanical, mechanical and chemical in association with cultural practices (Solomon *et al*, 2000). An economic and effective weed control measure in sugarcane is necessary for sustainability and economic viability of the sugarcane industry.

2.5 Common weeds in sugarcane

Sugarcane fields are infested with several weed species both annual and perennial which include broad leaf, grasses and sedges (Ismalia 2014). Weeds are a problem in the sugarcane production industry because the actual crop establishment itself requires wider raw spacing (Ismalia*,* 2014) and the actual growth rate of the crop at its early stages of its establishment is very slow such that some sugarcane varieties take 30 to 45 days to germinate and some take up to 60 to 75 days to reach full canopy (Danawale, 2012).

Sugarcane suffers massive weed infestations due to the fact that it is grown under abundant moisture and heavy nutrient supply that can be favourable t to early weed establishment in the sugarcane field (Ismalia, 2014) In ratoon crops, there is limited land preparation and as a result the chances of weeds perpetuation from season to season are high since they would have established well from the previous season. Major weed species observed mostly in sugarcane established fields are the sedges (*Cyperus rotundus and Cyperus esculentus*), the grasses include *Cynodon dactylon, Imperata cylindrica*, *Sorghum halepense*, *Pannicum* sp, *Dactylectomium aegyptium*, *Rottboelia* sp. and *Eleusine indica*.

Broad leaved weeds found in sugarcane fields mostly are *Chenopodium album*, *Convolvulus arvensis, Amarathus viridis*, *Portulaca oleraceae, Commelina benghalensis* (Ismalia, 2014). The most stubborn weeds in sugarcane fields are *Cynodon dactylon*, *Imperata cylindrica*, *Cyperus* sp and *Commelina benghalensis* due to their massive capacity to persist in the sugarcane fields and the complexity in their control methods.

2.6 Economic importance of weeds.

Weeds are a serious pest in any crop production industry. Weeds can either causes direct loses to the crop or indirect loses. Direct loses are classified as the losses that affect the quantity of crop produced or cash return from the crop after selling the produce (Aldrich and Kremer, 1998). Indirect losses are those losses that increase the costs to the production system as a result of presence of weeds but don't represent a decrease in cash return (Aldrich, 1998).

Examples of Indirect losses due to weeds include:

(i) Harbouring of insect pests and disease will increase cost of pest management.

(ii) Shorter ratoon cycles in sugarcane production leading to more frequent ploughing and planting which are very costly operations.

(iii) Reduction in labour productivities due to massive weed infestation leading to increased man-days and hence more expenditure in production.

(iv) Creation of fire safety hazards due to presence of weeds.

(v) Extraneous matter to the mill means more bagasse and this lead to sequestration of sucrose in the bagasse and hence high fibre per cent cane.

Weed management represent a major cost item in the food production industry (Glenn 1975). The total global cost to agriculture as a result of pests is slightly over $12 billion/year and weed control constitutes 42% of the total cost (Glenn, 1975). In 1991, the estimated average annual monetary loss caused by weeds in the United States was $4.1 billion. Of this loss, 82 % occurred in field crops (Anderson, 1996). For Mafambisse estate, a total of US$ 1 955 954.00 was the total weed control cost for the estate in the 2013 -14 production season (Tongaat Hulett Annual Report, 2014)

Weeds can also increase the cost of farm management cost if unchecked. Rijn (2000) expressed that extra costs on farm management by weeds can be expressed in various ways besides the actual direct influence in the cost of removing the weed through various control options. He pointed out that on farms where hand weeding is used as a weed management option and there is labour scarcity, the probability that the farm will be totally invaded by weeds is high and hence the need to source extra funds to eradicate the weeds which will eventually increase cost of farm management. Yadava (1993) claimed that an estimated yield loss of 10% can happen due to weed infestation where ordinary weed control measures are being employed. Solomon (2000) reiterated that losses up to 40% in sugarcane have been recorded due to uncontrolled growth of weeds in sugarcane fields.

2.7 Weed control systems

2.7.1 Mechanical weed control

Mechanical weed control involves the use of tools that are employed as a mechanism of removal of weeds from where they are not desired (Reddy, 1999)

This involves the use of three strategies namely:

(i) Prevention of spread of weed seeds by destroying weeds in the surrounding areas close to farming land.

(ii) Destruction of above ground vegetative portion of weeds by means of hand pulling, hoeing, and tillage operations such as ploughing, harrowing, disking and eventually burning.

(iii) Destruction of underground parts of weeds by digging or deep ploughing (Sundara, 1998)

At Mafambisse estate mechanical weed control is manually done using hoes. Land preparation is as well practised as a way to prepare the seed bed at the same time destroying weed seeds. High dependence on labour where labour is scarce, alternatives have to be looked into so as to find possible ways to reduce weed pressure in sugarcane fields (Sundara, 1998). Mechanical weed control is very limited to certain conditions for example in water logged conditions. This method of weed control is not so effective and cost effective due to reduced labour productivity under these conditions (Sundara, 1998) Mechanical weed control is dependent on soil type and not effective to certain weed species such as *Cynodon* and *Cyperus* sp. (Danawale, 2002).

One of the mechanical weed control systems is burial. This method is mostly effective on annual weeds in which all the growing points are buried (Vernon, 1997). Burial is usually less effective on perennial weeds which have underground stems and roots and are capable of regrowth from these underground storage organs. Another method of mechanical control is cultivation. The main objective in cultivation is to cut the root system of the weeds; deep cultivation should usually be avoided due to damage to the crop roots (Vernon 1997). Deep cultivation can also bring more weed seed to the surface where they will be exposed to conditions for germination. Most studies have shown that when weeds can be controlled without cultivation, there is no advantage to cultivating. In fact, there may be disadvantages such as drying out of the soil surface, bringing weed seed to the surface, and disturbing the root system of the sitting crop.

2.7.2 Competition

Crop competition is usually one of the most economical and best methods of weed control. However, this system is often one of the most overlooked methods (Vernon, 1997). Weeds compete with crops for space, light, moisture, nutrients, and carbon dioxide. The plant which starts first and is growing under ideal conditions will have the competitive advantage over the other. Factors such as planting date, row spacing, seeding rate, planting depth, soil moisture, soil fertility, and soil pH have an influence on the competitive advantage of the crop or weed (Sundara, 1998). Most of the crop plants have been developed under conditions which were as near optimum as possible for that crop. Therefore, everything that can be done to simulate these conditions for the crop plant should be in its favour. Since weeds have not been developed by plant breeders for specific conditions, they are often more tolerant to wide range of conditions and are well adapted to these conditions (Klingman, 1975). Usually there is only one crop species planted but there are many weed species that will be available in a field to compete with this crop. For example, as soil pH becomes limiting for the crop there is usually a weed species which is tolerant of that pH level and will out compete the crop (Aldrich, 1984). This is also true for factors such as fertility, soil moisture, and depth of emergence. Planting the crop at the optimum soil temperature, depth, soil moisture, soil fertility, and soil pH will allow it to emerge most rapidly and hence more competitive the crop will be and hence suppression to weeds (Vernon, 1997).

2.7.3 Crop Rotation

In a monoculture environment, usually there will be some weed or weeds which are tolerant and favoured by the cultural practices and herbicides used (Owen, 1984). By practising crop rotation with other crops, many of the cultural practices and herbicide programs are changed. This often will reduce the population of specific weeds which were tolerant in the previous crop (Aston, 1991). This system is not very practical as a weed control tool to sugarcane production since sugarcane is produced in a monoculture cropping system. This is mainly done at plough out as a pest control tool to break the pest and disease cycles (Kropff, 1993).

2.7.4 Biological Control

Biological weed control as a practical tool has not been widely utilized in control of weeds in commercial crop production (Smith, 1995). However, there have been some instances of successful biological control programs but have been not all that frequent. This is an area which still needs further research to find out its applicability in commercial production (Ashton, 1991). Insects, disease, and nematodes do naturally suppress growth of certain plants species in a continual process in the field. One area of weed science which should be recognized is how the use of fungicides, nematicides, and insecticides influence weed populations (Ross, 1985). There has been considerable work in the biological control of aquatic weeds. Three insects have been introduced into the United States, including Florida, for control of water-hyacinth. Additional insects have now been introduced to control other aquatic weeds in Florida. In addition, the Florida Game and Fresh Water Fish Commission has a permit system which enables the public to use grass carp for control of submersed, emergent, and other aquatic weeds (Vernon *et al*, 1997).

2.7.5 Chemical weed control

This involves use of herbicides to prevent germination of weeds, kill the germinated weeds or kill perennial weeds that cannot be removed by hand due to their re growth characteristics (Rijin, 2000). Herbicides can either be classified as pre- emergent or post emergent (Gupta, 2000).

2.7.5.1 Pre plant herbicides

These are herbicides that are applied before sowing or along with sowing of seeds (Gupta, 2000). In most cases when these materials are incorporated into the soil, they are called pre-plant incorporated treatments (PPI) (Gupta, 2000). The advantage of these incorporated treatments is that the herbicide is placed in the zone where weed seed is likely to germinate and is not dependent on rainfall to move the herbicide into this zone (Vernon *et al*, 1997). This type of treatment adds an extra cost on production which is the cost of incorporation of the product and requires that the crop be tolerant of the herbicide, as the crop seed and the herbicide will be in contact. Examples of such herbicides are trifluralin, profluralin, benefin, and vernolate.

2.7.5.2 Pre-emergent herbicides

These are herbicides that are applied soon after seed establishment and before the emergence of weeds (Gupta, 2000). These are soil active components, effective against a wide range of weeds germinating from seeds. Normally when applied they have to be activated by irrigation or rain so that they can form a herbicide seal in the soil to control all the germinating weeds (Gupta, 2000). However, strictly speaking, pre-emergence may apply to other situations such as pre-emergence to the crop, pre-emergence to the weeds, or pre-emergence to both crop and weed (Yadava, 1993). If the herbicide is not moved into the soil where the weed seed are located it will not be effective. If left on the soil surface, these herbicides are often lost due to photodecomposition and vaporization (Vernon *et al*, 1997).

2.7.5.3 Post emergent herbicides

These treatments are applied following the emergence of either the crop or weeds. If the crop has emerged but no weeds are present, then the application can be classified as post emergence to the crop but pre-emergence to the weeds (Vernon *et al*, 1997). If the crop and weeds have emerged, then the application is post emergence to both the weed and the crop and would be applied to the foliage of the weeds as a directed application. In this category of herbicides, there are selective and non-selective treatments. Selective herbicides can be selective to the crop or to the weeds (Smith, 1995). Non selective treatments are those that kill both the crop and weed when applied. Another category of post emergent herbicides are either systemic or contact treatments. Systemic treatments are those that need to get entrance into the translocation system of the plant to reach the target action area to interfere with the metabolic processes of the plant (Rijin, 2000). The contacts treatments need not to translocate but they act on the contact area.

2.7.6 Integrated weed management

Integrated weed management involves use of various measures or options employed in weed management in combination to achieve the best weed control system. This involves integration of mechanical, cultural, cropping, biological and chemical practices (Sundara, 1998). This will be in combination at various crops and weed growth stages to get the practical and economical results.

2.8 Herbicide mode of action

2.8.1 Hexazinone

Hexazinone herbicide belongs to the Methyl Thiotriazines family. It's a systemic herbicide that act by inhibiting photosynthesis in susceptible plants by diverting highly reactive molecules into a chain reaction that destroys chloroplast and cell membranes and their vital compounds (Tu, 2001). It is usually applied as a pre-emergent herbicide and soil must be moist to activate the herbicide. The herbicide works by binding to a protein component of the Photo system 11 complex which blocks electron transport (Aston *et al,* 1991). The result is a chain reaction in which triplet state chlorophyll reacts with oxygen to form singlet oxygen and both the chlorophyll and the singlet oxygen strip hydrogen ions (H^+)from unsaturated lipids in the cell and organelle membranes producing lipids radicals (Tu, 2001). The lipid radicals in turn attack and oxidise other lipids and proteins, resulting in the loss of cell and organelle membrane integrity, loss chlorophyll and carotenoids, leakage of cellular contents, cell death and ultimately death of the plant. Other family members such as Ametryne 500EC, Diuron and Metribuzin (Extreme plus) have similar mode of action of interfering with the photosynthesis process of the plant.

2.8.2 Pendimethalin 500 EC

This is a selective herbicide under the Dinitroaniline family and is effective against most annual grasses and several broad leaved weeds. It is generally incorporated into soil before seeding crops. It acts as an inhibitor of microtubule formation, disrupting cell division and causing disorientation (Huston, 1998).

2.8.3 Gramoxone

It is commonly known as Paraquat. It is a broad spectrum, non-selective contact herbicide used to control both grasses and broad leaved weeds. Paraquat residues are absorbed and translocated in the xylem, activated by light in the plant photosynthesis process (Huston, 1998). It damages the plant cells by interfering with electron transport system and formation of superoxides that attack unsaturated membrane fatty acids , rapidly opening and disintegrating cell membranes and tissues.

2.8.4 MCPA (2-methyl-4-chlorophenoxyacetic acid)

It is usually applied as a post emergent herbicide to control annual weeds and perennial broad leaved weeds in a range of crops. It acts as a selective, systemic, hormone-type herbicide. MCPA translocates and concentrates in the meristematic regions where it inhibits growth in a similar manner to the Auxin -3-Indoleacetic acid (IAA) (Huston, 1998). At the molecular level, it influences levels of RNA and DNA polymerase and levels of enzymes involved in the normal growth and development process.

2.8.5 Tebuthiuron (Tebusan)

Mainly used for control of herbaceous and woody plants in non-cropping areas. It also controls grasses and broad leaved weeds in plantation agriculture (Huston, 1998). It works through inhibition of Photosystem 11 electron transport (PS11)

2.8.6 Harness

This belongs to the Acetanilides family. This is mainly applied as a pre-emergent treatment or pre plant for control of annual grasses and some annual broad leaved weeds. Some popular herbicides within this category are Lasso, Bullet, Guardian and Dual. This works by interfering with cell division and protein synthesis of the plant (Burton, 2014).

2.9 Specific weeds

2.9.1 *Rotboellia cochinchinensis* L

Itch grass is an annual grass that is native to tropical Southeast Asia. Itch grass is commonly 90 cm to 180 cm tall, but can grow 300 cm high if left unchecked. Itch grass seeds spread via road construction equipment, farm machinery, birds, and wind. This annual grassy weed is similar in appearance to Johnson grass. However, itch grass can be identified by pale green colour, prop roots, cylindrical spike inflorescences and seed, and long, sharp siliceous hairs on the leaf sheaths and much of the plant. The sharp hairs can penetrate skin causing irritation, hence the common name.

2.9.*2* ***Cyperus esculentus*** L.

Cyperus esculentus L. belongs to the family Cyperaceae. It is a perennial, C4 graminoid although occasionally a summer – fall annual in some areas (Anderson, 1991). Foliage dies back with cool temperatures in the fall and tubers survive and respond to the following summer or go up to several years later. It reproduces by seeds, creeping rhizomes and tubers. *Cyperus esculentus* L. is a tough single stemmed erect perennial growing up to 90 cm tall. Underground along with fibrous roots are many slender rhizomes which form a tuber at the end. Its rooting system is characterised by an extensive and complex system of fine, fibrous and scary rhizomes with small hard spherical tubers and basal bulbs. Leaves are grass like, basal erect approximately equal to or longer than culms up to 90 cm or more bracts like forming an involucres subtending the flower (Ross, 1985).

2.9.3 ***Sorghum halepense*** L.

Sorghum halepense usually is a tall grass with spikelets having one functional flower and two glumes. Disarticulation (seed shedding) occurs below the glumes, leaving a bare rachis with small "suction-cup" ends. Spikelets in cross-section are nearly round.

Spikelets are of two kinds; one sessile and fertile, the other pedicelled and staminate (or neuter). The panicle is usually diffuse and delicate. The plants are perennials with scaly underground rhizomes (Smith, 1995).

2.9.4 *Ipomea purpurea* L.

The species is native to Central America, but has adapted to tropical, subtropical, and warm temperate regions of the world. This annual plant has simple, alternate, pinnately veined leaves with entire margins. Leaves are ovate with cordate bases and acute or acuminate tips, ranging from 1-11 cm in length and 1- 12 cm in width. The stems are branched or simple, loosely pubescent to tomentose with short appressed trichomes. They are sparsely hirsute to glabrate. The petioles range from 1-14 cm long (http***//www.mossiouriplan.com)***. *Ipomoea purpurea* relies primarily on insect pollination, but is also capable of self-fertilization. About 30% of the flowers are self-pollinated. This 30% consists of lighter coloured flowers. Cross-pollination occurs mostly by bumblebees and small butterflies. The fruit is a subglobose to ovoid capsule that is approximately 1cm in diameter and up to 2.5cm long. It is 6-valvate and contains 3-6 seeds. The seed surface is granular, dull brown to black in colour, and densely covered with small, brown hairs. The seeds are from 4 to 5.7 mm long. They are wedge shaped, with a horseshoe-shaped scar. Seed dispersal is by wind, rain, and gravity. Seeds also can be spread by birds and by human activities via contaminated crop and flower seeds**.**

2.9.5 *Eleusine indica* L.

It is a caespitose annual grass introduced from old world (Ford, 1964). Plant genetic studies have indicated that it is one of the wild progenitors for domesticated finger millet (*Eleusine coracana*) in Africa. It is a contaminant in components that antedate European contact. The genus *Eleusine* has nine species. *Eleusine tristachya* is the only member of the genus that is native to the new world. Usually it grows to a height of 1 meter or less. It is a tufted annual grass easily recognised for its narrow dense spikes, about four of which emanate from the terminus of each culm. Its seeds are available in the late summer and early winter.

2.10 Sugarcane variety characteristics

2.10.1 N19 Variety

This variety originated from Natal region of South Africa. It has high sucrose content at maturity and as well offers a relatively higher resistance to smut disease. It is best suited to annual season harvesting (http://www.sugar.org.za/sasri/variety/index.htm, 2006).

It has a high tolerance to Aluminium toxicity and has a high nitrogen use efficiency that is, it does well on low application rates of N- fertilizer. Good yields are obtained on moderate depth soils on clay content higher that 20%. Recommended for both rain fed and irrigated production systems. It has good milling characteristics and very low pith. It has speedy and reliable germination and has high stalk mass at harvest. N19 has average stalk height at harvest and an average stalk population at harvest of 112 000/ ha. Has vigorous growth with a rapid stalk elongation and canopies very fast which gives it a competitive advantage over weed pressure. After harvesting, its rationing ability is very fast (http://www.sugar.org.za/sasri/variety/index.htm, 2006).

2.10.2 N23 Variety

N23 is a variety with high resistance to diseases. It often does well on less favourable or moderate soils. Generally is a low yielding variety but has high yield stability over ratoons. It is recommended to mid-season harvesting but very good yields are obtained on early season. N23 is a heavy flowing variety and is not suitable to poorly drained soils. Not recommended on very sand soils. Has high pith to fibre ratio and hence poor milling qualities. Germination is poor in cold environments and as well in very wet soil conditions. N23 has high stalk population at harvest averaging 134 000 /ha. It has a medium stalk mass at harvest due to its average stalk height at harvest. It grows fast and has a rapid canopy formation and very good rationing ability. (http://www.sugar.org.za/sasri/variety/index.htm, 2006).

2.10.3 N21 Variety

This variety has very good germination vigour and it grows very fast. Best suited to shallow soils and strives well under drought conditions. N21 is a self-trashing variety and hence suitable to green harvesting. Has high nitrogen use efficiency. It out performs other varieties on shallow soils and on hill tops. High tolerance to Aluminium toxicity and it's a lodging variety. Has high fibre content and is hard to cut. Delayed canopy due to erectophile structure and this can lead to weed problems. Recommended to closer raw spacing (1 meter raw spacing). Average talk population at harvest of 110 000/ha (http://www.sugar.org.za/sasri/variety/index.htm, 2006).

2.10.4 N27 Variety

This is an all season variety with high RV yield. N27 Performs well under water stressed conditions. Yields are generally low on plant cane but higher yields on ratoon cane. Tolerant to water logging and has moderate tolerance to Al toxicity. N27 is a slow germinator and is suitable on soils with high clay content. Average stalk mass at harvest and average stalk population at harvest is 122 000/ha. Slow canopy in plant cane, but rapid canopy in ratoon cane. Average stalk height at harvest. (http://www.sugar.org.za/sasri/variety/index.htm, 2006).

CHAPTER 3

METHODOLOGY

3.1 Description of Site

The trials were carried out at Mafambisse Sugar Estate in sofala province of Mozambique. The research was done in two seasons that is 2012/13 season as plant cane and 2013/14 season as first ratoon crop. Mafambisse Estate is located 50 km off the coast from Indian Ocean at an altitude of about 7 metres. The average annual temperatures range around 30°C. Mafambisse receives an annual rainfall of between 800- 1000mm /year and the rain season runs from November up to March. The total area under cane at Mafambisse Estate is 7500 ha. The sugarcane at Mafambisse is all under irrigation. The research was carried out on vertisol soil which is mixed with sedimentation from the flooding along Pungwe River.

3.2 Field Operations

3.2.1 Plant cane

The field was ploughed by a roam disc tractor pulled to a depth of 25 cm. The ploughing was carried out in June 2013. The first plough was done the first week of June 2013 and the second plough came in two weeks later with the same implement. Two weeks after the second plough, land plane was done to level the seed bed and as well create gradient for proper movement of water and to facilitate drainage. After land plane, ridging was done to the trial areas at a depth of 10 to 15 cm. After ridging, basal fertilizer MAP (N11-P22-K00) at a rate of 318 kg/ha was applied on the 28 of June 2013 on both sites the flood irrigated and the sprinkler irrigate site. The application rate used was the recommended for the estate. Planting was carried out on the 3rd of July 2013 for the furrow irrigated trial and on the 4th of July 2013 for the sprinkler irrigate trial. Four varieties namely N19, N21, N23 and N27 were used in the experiment. These varieties were selected on the basis of their historical performance on the estate. A seed rate of 10 t/ha was used for all varieties and numbers of buds were counted per meter for germination analysis. First irrigation was done the same day planting was done and this was aimed at bringing the soil to field capacity. An irrigation application depth of 55 mm was done for the furrow irrigated plot and 55 mm for the sprinkler irrigated so as to bring soil to field capacity. For sprinkler irrigated plot, a sprinkler nozzle of 5.5mm/hour was used at a standing time of 10 hours. For furrow irrigated, siphons of 3l/s were used during the whole experiment. Recommended herbicides for plant cane namely Pendimethalin 500EC at a rate of 3.5 L/ha, Extreme plus at a rate of 1.2kg/ha and MCPA at a rate of 3.0 L/ha as one mixture. These herbicides were applied specifically to the treatments that were supposed to be applied. Herbicide application was done 4 DAP and after first irrigation. Post emergent herbicides were applied at 10 WAP, and the following herbicides were used as a tank mixture: Harness at 2.8L/Ha, Ametryne at 4l/ha and Gramoxone at 1L/ha. At 12 weeks, Urea application was done to the cane at a rate of 250kg/ha (115 kgsN/ha) 12 WAP. Manual weeding was carried out as stipulated in the trial design to those treatments that required the activity. After 12 months the sugarcane was harvested for yield and quality analysis.

3.2.2 Ratoon Cane

In the 2013/14 season, the same experiment was repeated on the same plots as ratoon cane. After harvest of the plant cane, Irrigation at 55 mm was applied to bring back the soil to field capacity after a dry off period of 8 weeks. Fertilizer application of a blend of 5.1.5 (N24.5-P4-K24.5) was used at a rate of 700 kg/ha which translated to 140kgN/ha, 28kgP/ha and 140kgK/ha. This was applied within one week after harvesting. 7 DAC, Pre-emergent herbicides namely Pendimethalin 500 EC at 3.5L/Ha, Extreme plus at 1.2 kg/ha and Hexazinone 240 SL at 1.5L/ha as a tank mixture and applications were only to treatments that were supposed to be applied herbicide. Post emergent herbicide application came in after 70 DAC with Tebusan 500 SC at 1.5L/ha, Diuron 80 at 2.5L/ha and Foliwet 900 at 0.6L/ha. Manual weeding was carried out to the respective plots as per the trial design.

3.3 Treatments, Trial design and Establishment

3.3.1 Design

The experiment was set out in a completely randomized design with all the treatments randomly located in the trial plot. There were two trial sites; one was under furrow irrigation and the other one was under sprinkler irrigation. Rain gauges were set up on both sites for rain measurements throughout the whole production cycle of the trials to monitor the rainfall factor.

3.3.2 Treatments

Four treatments were used in this trial.

C - Control experiment where no weed control method was applied

T1 - Manual weed control only

T2 - Chemical weed control only

T3 - A combination of chemical and manual weed control in association

Each variety was subjected to all the treatments and each treatment on each variety was replicated four times. Each trial plot had 64 sub plots both on furrow and sprinkler irrigated.

3.4 Trial establishment

Four treatments Control, manual weeding only, chemical weed control and a combination of manual and chemical weed control were investigated on their influence on all the measured variables of the research on four varieties namely N19, N21, N23 and N27. Each treatment was replicated four times on each and every variety within a trial plot. These treatments were randomly allocated in the trial block. Each sub plot was made up of 5 lines of 5 meters long at an inter row spacing of 1.5 meters. This translated to 37.5 m^2 $_{per}$ sub plot and the whole trial plot was 2400 m^2. The seeding rate was 10 tons per ha and planting of sugarcane sets furrows was done at a depth of 10-15 cm and a space of 1 meter was left between the sub plots in the trial plot.

3.5 Procedure

Five (5) weeks after planting, on the established points in each sub plot, counting of germinated cane was done to evaluate the germination percent on each and every plot. This information was collected only to be used as a specific reference to the results of the experiment. This was done so that it will be possible to trace the actual influence of weeds on yield of sugarcane. Irrigation scheduling was done using the profit and loss method based on the Eto from the A plan. The depletion level that was used as acceptable was at 50 % and the refill point which was used on these soils was 30 mm. Top dressing of the trials was carried out at 12 weeks after planting with Urea at a rate of 250 kg Urea (115kgN/ha) and for the ratoon cane, 5.1.5 (48) fertilizer blend was used as per the recommendation. This top dress was at a rate of 700 kg/ha (140kgN/ha) the first week after cutting. The treatments T1 and T3 where manual weeding was employed, fertilizer application was done on cleaned subplots and for manual weeding only, weeding was done at 60 and 90 DAP. For T3, 2 weeding operations were done at 45 and 90 DAP with pre-emergent herbicide application coming first and post emergent coming after first weeding and before second weeding. T3 treatment was used as a standard being used at the Estate and was subjected to comparison with other weed control options. All the measurements done were carried out on the net plot of each and every sub plot which was made up of 3 lines of cane, 4 meters long. The end lines were considered for border effect and 0.5 m from each end of the lines was removed.

3.6 Data collection/Variables measured

The following variables were measured:

1. Height measurements were carried out using a 30 cm ruler at the set out growth measurement points on each and every sub plot of the trial site. This was done on monthly basis from 5 months up to 10 months when the trial was subjected to dry off period preparation for harvesting. An identified stick of cane at the site was measured.
2. Stalk thickness was measured from 5 months up to 10 months. From 5 months and above, this is called grant growth stage when cane will be producing the yield.

3. Prior to harvesting, cane samples were taken to the cane testing laboratory for quality analysis where the Pol% cane (sucrose determination), the Brix, Fibre percent cane and moisture were established for each and every treatment.
4. After harvesting, yield determination was done by weighing the total cane from the net plot of each every sub plot.
5. Gross margin analysis will be carried for all the treatments in each variety.

The yield data was taken from a net plot of each and every sub plot. The net plot was 18m2 of the 37.5m2 of the gross plot.

3.7 Statistical analysis

The statistical package, Genstat Discovery 14th Edition was used to analyse the data. All the data were subjected to an analysis of variance (ANOVA) and treatment means were separated using the Least Significance Difference (LSD) test at $p<0.05$ except for the gross margin data. A two way ANOVA was used.

CHAPTER 4

DATA PRESENTATION ANALYSIS AND INTERPRETATION

4.1 Effect of treatments on stalk height (cm)

4.1.1 Effect of treatments on cane stalk height (cm) for plant cane under sprinkler irrigation.

The effect of weed control options on sugarcane final stalk height is shown in Table 4.1.1. Control treatment or no weed control was significantly different to all other treatments in all the varieties and on the other treatments. Sugarcane height of N19 in the control was significantly different to all other treatments where some weed control were carried out at (Table 4.1.1). However for varieties N23 and N27, there was no significant difference in cane height in the hoeing, herbicide and combination treatments.

Table 4.1.1 Means for cane stalk height (cm) for plant cane under sprinkler irrigation.

	Varieties			
Treatments	**N19**	**N23**	**N21**	**N27**
Control	225.3^{a}	209.5^{a}	215.5^{a}	222^{a}
Hoeing	285.8^{b}	260.5^{b}	263.8^{b}	275.8^{b}
Herbicide	313.5^{c}	259.5^{b}	298^{c}	285^{b}
Herbicide +Hoeing	273.5^{b}	244^{b}	318.3^{c}	287.8^{b}

P Value	<0.001
$LSD_{0.05}$	27.2
C.V%	10.3

Means which do not share the same letter in the same column are significantly different at (P<0.05)

4.1.2 Effect of treatments on stalk thickness (cm) for plant cane under sprinkler irrigation

The stalk thickness of sugarcane is shown in the table 4.1.2. The sugarcane stalk thickness was not significantly different on all the treatments applied to N19 variety (LSD = 0.7). However there were some significant differences in stalk thickness in herbicide, hoeing and combination in varieties N23 and N27. In N21 variety, there were some significant differences amongst the treatments (P<0.05).

Table 4.1.2 Means for stalk thickness (cm) for plant cane under sprinkler irrigation.

	Varieties			
Treatments	N19	N23	N21	N27
Control	8.5^{a}	7.25^{a}	7.75^{a}	8^{a}
Hoeing	7.75^{a}	8.5^{a}	8^{ab}	8^{a}
Herbicide	8.5^{a}	7.75^{b}	9^{bc}	8.5^{b}
Herbicide + Hoeing	7.75^{a}	8.0^{b}	9.5^{c}	8.5^{a}

P Value	0.009
$LSD_{0.05}$	0.7
C.V%	8.5

Means which do not share the same letter in the same column are significantly different at (P<0.05

4.1.3 Effect of treatments on yield (t/ha) for plant cane under sprinkler irrigation

The yield of sugarcane (T/ha) for no weed control was significantly different to the rest of the treatments at (LSD= 8.06) in all the sugarcane varieties. However there was no significant difference (P<0.05) in yield in all varieties of sugarcane in the herbicide, hoeing and combination treatments. Weed control influenced the yield of sugarcane.

Table 4.1.3 Means for yield (t/ha) for plant cane under sprinkler irrigation

	Varieties			
Treatments	N19	N23	N21	N27
Control	43.9^{a}	38.1^{a}	41^{a}	34.1^{a}
Hoeing	69.1^{b}	60.2^{b}	71.4^{b}	69.8^{b}
Herbicide	70.9^{b}	60.5^{b}	68.4^{b}	70.4^{b}
Hoeing +herbicide	70.3^{b}	56.2^{b}	72^{b}	67.3^{b}

P value	< 0.001
LSD	8.06
C.V %	12.1

Means which do not share the same letter in the column are significantly different at (P<0.05)

4.1.4 Effect of treatments on Brix (%) content for plant cane under sprinkler irrigation

There was no interaction between the brix content of sugarcane varieties and the treatments. However the brix content of variety N21 was not significantly different in all the treatments. No weed control treatment was significantly different to other treatments in the N23 and N27 varieties (Table 4.1.4). This could be because brix content is influenced by other factors other than weed pressure during the growth of cane.

Table 4.1.4 Means for Brix (%) content for Plant cane under sprinkler irrigation

	Varieties			
Treatments	N19	N23	N21	N27
Control	17.81	15.48	17.05	15.8
Hoeing	17.1	17.18	17.12	17.49
Herbicide	16.23	17.18	17.24	17.8
Hoeing + herbicide	17.63	18.29	16.54	16.83

P value	Ns
$LSD_{0.05}$	1.18
C.V %	9.6

Ns denotes non-significant at (P>0.05). Means which do not share the same letter in the same column are significantly different.

4.1.5 Effect of treatments on sucrose (Pol %) for plant cane under sprinkler irrigation

The effect of different weed control treatment on sucrose content of sugarcane is shown in Table 4.1.5. The results indicate that no weeding treatment was significantly different to all other treatments in all the four sugarcane varieties (LSD= 0.78). However the sucrose content was not significantly different amongst the varieties in the herbicide, hoeing and combination treatment (P>0.05).

Table 4.1.5 Means for sucrose (Pol %) content for plant cane under sprinkler irrigation

	Sucrose (Pol %)			
	Varieties			
Treatments	N19	N23	N21	N27
Control	13.74	13.89	13.23	13.41
Hoeing	14.72	15.74	15.11	15.4
Herbicide	14.95	15.54	15.13	15.2
Hoeing + herbicide	15.19	15.93	14.6	14.64

P value	Ns
LSD	0.78
C.V %	7.2

Ns denotes non-significant at (P>0.05). Means which do not share the same letter in the same column are significantly different.

4.2 Effect of treatments on ratoon cane under sprinkler irrigation

4.2.1 Effect of treatments on final stalk height (cm) for ratoon cane under sprinkler irrigation

Ratoon cane of sprinkler irrigated showed a significant improvement in final stalk height of cane in varieties N19, N21 and N2 (LSD= 40.07). N23 variety as a slow grower didn't achieve good stalk height in the control treatment despite the advantage of the well-established rooting system as other varieties to compete with weeds. Varieties N21 and N27 obtained tallest stalks in hoeing and combination in N21 variety (Table 4.2.1) and in herbicide and combination treatments in variety N27 (Table 4.2.1)

Table 4.2.1 Means for stalk height (cm) for ratoon cane under sprinkler irrigation

	Varieties			
Treatments	**N19**	**N2**	**N2**	**N27**

		3	1	
Control	198.8[a]	161[a]	224[a]	200.5[a]
Hoeing	220.5[ab]	226.5[b]	310[a]	223.8[ab]
Herbicide	239.8[b]	222.8[b]	271.7[b]	272.5[b]
Herbicide+ Hoeing	228.8[ab]	187.5[ab]	301.5[b]	260.8[b]
P Value	0.027			
$LSD_{0.05}$	40.07			
C.V%	16.8			

Means which do not share the same letter in the same column are significantly different at (P<0.05)

4.2.2 Effect of treatments on final stalk thickness (cm) for ratoon cane under sprinkler irrigation

The results in Table 4.2.2 indicate that the stalk thickness was not significantly different (P>0.05) for all the treatments in the N19 and N23 varieties. However, some significant differences in stalk thickness were noticed in the herbicide treatment of N27 variety and also in the combination treatment of N23 (LSD= 1.45)

Table 4.2.2 Means for stalk thickness (cm) for ratoon cane under sprinkler irrigation

			Varieties	
Treatments	**N19**	**N23**	**N21**	**N27**
Control	7.75	6.25	8	7.25
Hoeing	8.25	7.75	8.25	7.5

Herbicide	7.75	7	7.67	8.5
Herbicide +Hoeing	7.75	8	7.5	7.75
P Value	Ns			
LSD	1.45			
C.V%	18.8			

4.2.3 Effect of treatments on yield (t/ha) for ratoon cane under sprinkler irrigation

The results indicate that there was a significant difference in the control treatment to all other treatments (P<0.05). The control treatment produced the lowest yield compared to the rest of the treatments in all the sugarcane varieties. However, highest yield of 72.3t/ha sugarcane was obtained in the hoeing treatment under the N21 variety.

Table 4.2.3 Means for yield(t/ha) for ratoon cane under sprinkler irrigation

	Varieties			
Treatments	**N19**	**N23**	**N21**	**N27**
Control	39.4^{a}	25.5^{a}	36.2^{a}	33.9^{a}
Hoeing	62.8^{c}	59.4^{c}	72.3^{c}	62.7^{b}
Herbicide	61.2^{c}	57.9^{bc}	68.8^{bc}	64.1^{b}

Herbicide+ hoeing	54.4^{b}	53.1^{b}	64.9^{b}	64.4^{b}
P value	0.001			
$LSD_{0.05}$	5.91			
C.V %	14.1			

Means which do not share the same letter in the same column differ significantly at ($P<0.05$).

4.2.4 Effect of treatments on Brix (%) content for ratoon cane under sprinkler irrigation

The Brix content obtained in the control treatment on all the varieties was significantly different to hoeing, herbicide and combination treatments (LSD=0.92). The lowest Brix content was obtained in the control treatment in all the varieties across the treatments.

Table 4.2.4 Means for Brix (%) content for ratoon cane under sprinkler irrigation

		Varieties		
Treatments	**N19**	**N23**	**N21**	**N27**
Control	16.6	16.92	15.66	16.41

Hoeing	17.78	18.31	18.32	17.09
Herbicide	18.19	17	18	17.78
Herbicide + Hoeing	17.41	18.26	18.02	17.48
P value	Ns			
$LSD_{0.05}$	0.92			
C.V %	7.2			

Ns denotes non-significant at (P>0.05).

4.2.5. Effect of treatments on sucrose (Pol %) for ratoon cane under sprinkler irrigation

The results in table 4.2.5 indicate that there was no significant difference in the sucrose content of sugarcane in all the treatment in all varieties (Table 4.2.5).

Table 4.2.5 Means for sucrose (Pol %) for ratoon cane under sprinkler irrigation

	Varieties			
Treatments	**N19**	**N23**	**N21**	**N27**

Control	15.5	15.12	14.71	15.45
Hoeing	15.25	15.58	15.19	15.19
Herbicide	15.14	14.94	14.64	15.29
Hoeing + herbicide	15.24	15.53	15.59	15.35
P value	Ns			
$LSD_{0.05}$	0.48			
C.V %	4.4			

Ns denotes non-significant at ($P>0.05$).

4.3 Effect of treatments on plant cane under flood irrigation

4.3.1 Effect of treatments on final stalk height (cm) for plant cane under flood irrigation

There was a significant difference in cane height in the plant cane flood irrigated cane as indicated in (Table 4.3.1) in no weeding treatment in varieties N19, N23; N21 and N27 ($P<0.05$). The lowest height of cane was obtained in N23 variety with 118.8 cm. The highest cane height was obtained in N21 variety with 244.82 cm in the herbicide treatment.

Table 4.3.1 Means for stalk height (cm) for plant cane under flood irrigation

	Varieties

Treatments	N19	N23	N21	N27
Control	209.8^{a}	175.3^{a}	256.3^{a}	212.5^{a}
Hoeing	267^{b}	227.3^{b}	315.5^{c}	276.8^{b}
Herbicide	277^{b}	248.5^{c}	281^{b}	271.3^{b}
Herbicide+ Hoeing	251.3^{b}	214.8^{b}	287^{b}	263.5^{b}
P Value	0.001			
$LSD_{0.05}$	20.78			
C.V%	8.2			

Means which do not share the same letter in the same column are significantly different at (P< 0.05).

4.3.2 Effect of treatments on final cane stalk thickness (cm) for plant cane under flood irrigation

The results in table 4.3.2 indicate that the stalk thickness was not significantly different across the treatments in varieties N19 and N23 (LSD=0.59). Control treatment in N27 was significantly different to the remainder of the treatments.

Table 4.3.2 Means for cane stalk thickness (cm) for plant cane under flood irrigation.

		Varieties		
Treatments	N19	N23	N21	N27

Control	8.25	7	7.75	7.5
Hoeing	8.25	7.75	8.75	8
Herbicide	8.25	7.25	7.25	8.25
Herbicide +Hoeing	7.75	7.25	7.75	8.25
P Value	Ns			
$LSD_{0.05}$	0.83			
C.V%	10.5			

Ns denotes non-significant at (P>0.05)

4.3.3 Effect of treatments on yield (t/ha) for plant cane under flood irrigation

There was significant difference in yield (t/ha) (P<0.05) in all the varieties to the rest of the treatments (Table 4.3.3) Results indicate that N23 obtained the least yield of 12.02t/ha in the control treatment compared to 64.25t/ha, 42.94t/ha and 38.9t/ha for varieties N19, N21 and N27 respectively (Table 4.3.3).

Table 4.3.3 Means for yield (t/ha) for plant cane under flood irrigation.

	Varieties			
Treatments	**N19**	**N23**	**N21**	**N27**

Control	64.25[a]	12.02[a]	42.95[a]	38.9[a]
Hoeing	70.2[b]	60.55[b]	80.28[d]	63.85[b]
Herbicide	73.72[b]	60.72[b]	67.7[b]	65.37[b]
Hoeing+ herbicide	69.07[ab]	62.23[b]	74.92[c]	71.28[c]
P value	<0.001			
LSD	4.95			
C.V %	10.9			

Means which do not share the same letter in the same column are significantly different at (P<0.05).

4.3.4 Effect of treatments on sucrose content (Pol %) for plant cane under flood irrigation.

The sucrose content of N19 in control was significantly different (P<0.05) in comparison with the herbicide, hoeing and combination (LSD=4.9). There was also the same trend in varieties N21 and N27. However, there was no significant difference if sucrose level across the treatments in the variety N23 (Table 4.3.4)

Table 4.3.4 Means for sucrose content (Pol %) for plant cane under flood irrigation

	Varieties			
Treatments	**N19**	**N23**	**N21**	**N27**

Control	15.17[a]	15.16	13.88[a]	13.53[a]
Hoeing	15.99[b]	15.14	15.34[b]	14.25[b]
Herbicide	16.26[a]	15.65	15.4[b]	14.93[b]
Hoeing+herbicide	16.22[b]	15.09	14.98[b]	15.13[c]
P value	<0.001			
LSD	0.68			
C.V %	6.3			

Means which do not share the same letter in the same column are significantly different at (P<0.05).

4.3.5 Effect of treatments on Brix content (%) for plant cane under flood irrigation

Significant differences in Brix content in varieties N19, N21 and N27 (LSD=0.86). However lower Brix levels were obtained in the control treatment in comparison with other treatments in the same varieties. No significant difference in Brix content in the N23 variety (Table 4.3.5).

Table 4.3.5 Means for Brix (%) content for plant cane under flood irrigation

	Varieties

Treatments	N19	N23	N21	N27
Control	17.2[a]	16.87	17.44[a]	15.88[a]
Hoeing	18.3[b]	17.15	17.15[a]	15.15[a]
Herbicide	18.1[b]	17.26	18[b]	17.06[b]
Herbicide +Hoeing	17.37[a]	16.92	16.71[a]	16.69[b]
P value	0.006			
LSD	0.86			
C.V %	7.1			

Means which do not share the same letter in the same column are significantly different at ($P< 0.05$).

4.4 Effect of treatments on ratoon cane under flood irrigation.

There were significant differences in cane stalk height ($P<0.05$) across the treatments and varieties. Generally shorter cane was observed in the control experiment as compared to the weed controlled treatments. Massive biomass accumulation was evidenced in the N21 variety through achieving best height of cane (Table 4.4.1)

4.4.1 Effect of treatments on final stalk height (cm) for ratoon cane under flood irrigation.

The results indicate that there was a significant difference between the control treatment of all varieties and the rest of the treatments (LSD=20.74). Generally shorter cane was produced in the control treatment and taller cane from all the treatments where some form of weed control were carried out (Table 4.4.1).

Table 4.4.1 Means for stalk height (cm) for ratoon cane under furrow irrigation

	Varieties			
Treatments	**N19**	**N23**	**N21**	**N27**
Control	218.3[a]	221[a]	263.3[a]	243.5[a]
Hoeing	245.3[ab]	233.3[a]	303.8[b]	268[b]
Herbicide	279.8[b]	270.3[b]	340.8[b]	294.3[b]
Herbicide +Hoeing	253.3[b]	232[a]	298.5[b]	277.3[b]
P Value	0.003			
LSD	35.61			
C.V%	13.4			

Means which do not share the same letter in the same column are significantly different at 0.05 probability level.

4.4.2 Effect of treatments on final cane stalk thickness (cm) for ratoon cane under flood irrigation

Stalk thickness was not significantly different (P>0.05) for all the varieties and all the treatments (Table 4.4.2). There was no interaction between the variety and treatments to influence the stalk thickness.

Table 4.4.2 Means for cane stalk thickness (cm) for ratoon cane under flood irrigation

		Varieties		
Treatments	**N19**	**N23**	**N21**	**N27**
Control	7.75	8.25	7.25	7.75
Hoeing	7.75	8.25	8.75	8.5
Herbicide	8.25	7.75	8.5	8.75
Herbicide + Hoeing	7.75	8.25	7.75	8.5
P Value	Ns			
$LSD_{0.05}$	0.88			
C.V%	10.8			

4.4.3 Effect of treatments on yield (t/ha) for ratoon cane under flood irrigation

The results indicate that there were significant differences in yield of N21 variety between the control treatment and the rest of the treatments ($P<0.05$). Variety N23 obtained the lowest average yield of 6.1 t/ha in the control compared to 34.1 t/ha in N19 variety, 49.6 t/ha in N21 and 53 t/ha in N27 (Table 4.4.3). Average yields were obtained in the treatments where some weed control activities were carried out.

Table 4.4.3 Means for yield (t/ha) for ratoon cane under flood irrigation

	Varieties			
Treatments	**N19**	**N23**	**N21**	**N27**
Control	34.1^{a}	6.1^{a}	49.6^{a}	53^{a}
Hoeing	61^{b}	50.6^{b}	71.6^{b}	57^{a}
Herbicide	63.3^{b}	63.7c	69.8^{b}	60.9a
Herbicide+Hoeing	57.6^{b}	55.9^{bc}	74.8^{b}	66.7^{b}
P value	<0.001			
LSD	7.9			
C.V %	19.2			

Means which do not share the same letter in the same column are significantly different at (P<0.05).

4.4.4 Effect of treatments on sucrose content (Pol %) for ratoon cane under flood irrigation

The results indicate that there was significant difference in the sucrose content (P<0.05) (Table 4.4.4). Generally the sucrose content in the control treatment was lower than the other treatment in almost all the varieties except hoeing under N27 where the sucrose content obtained was 14.26 % (Table 4.4.4). Weeds compete for nutrients with weeds and in control, the sucrose content was lower in relation to the rest of the treatments probably due to the crop being deprived of the crucial nutrient which is potassium which contributes a lot to sucrose content.

Table 4.4.4 Means for sucrose content (Pol %) for ratoon cane under flood irrigation

	Varieties			
Treatments	**N19**	**N23**	**N21**	**N27**
Control	14.4^{a}	14.72^{a}	14.21^{a}	14.73^{a}
Hoeing	15.64^{b}	14.97^{ab}	15.43^{b}	14.26^{a}
Herbicide	15.37^{b}	15.07^{ab}	15.04^{b}	15.49^{b}
Herbicide +Hoeing	15.98^{b}	15.57^{b}	15.24^{b}	15.78^{b}
P value	<0.001			
LSD	0.68			
C.V %	6.3			

Means which do not share the same letter in the same column are significantly different at (P<0.05).

4.4.5 Effect of treatments on Brix content (%) for ratoon cane under flood irrigation

Brix is a close indicator of sucrose content. The same trend in sucrose content was followed in the brix content. The results shows that there was a significant difference in Brix content (P<0.05) between the control where weeding was nor done and the rest of the treatments in almost all the varieties. However there was a similar drop in

Brix content (16.55%) (Table 4.4.5) in N27 as what happened with sucrose under hoeing treatment.

Table 4.4.5 Means for Brix (%) content for ratoon cane under flood irrigation

	Varieties			
Treatments	**N19**	**N23**	**N21**	**N27**
Control	16.07[a]	16.9[a]	16.33[a]	16[a]
Hoeing	17.53[b]	17.34[b]	16.99[ab]	16.55[b]
Herbicide	17.29[b]	18.59[c]	17.38[b]	17.64[c]
Herbicide+ Hoeing	17.99[b]	18.43[c]	17.76[b]	17.31[bc]
P value	0.024			
$LSD_{0.05}$	0.89			
C.V %	7.2			

Means which do not share the same letter in the same column are significantly different at 0.05 probability level

4.5 Gross margin analysis

4.5.1 Effect of treatments on gross margin ($/ha) for plant cane under sprinkler irrigation

Based on the farmer price which was paid to the sugarcane farmers after selling their cane to the mill, the control treatment in all varieties declared losses with N27 producing the highest loss of $517.05 per ha (Table 4.5.1). The yields which were obtained in the control treatment were below the breakeven and hence losses were earned. Losses were also registered in hoeing and combination treatments of N23, (Table 4.5.1).

Table 4.5.1 Income ($/ha) for plant cane under sprinkler irrigation

Gross Margins for Plant cane sprinkler irrigated (Income $/ha)

	Varieties			
Treatments	N19	N23	N21	N27
Control	-251	-406.69	-345.93	-517.05
Hoeing	221.11	-31.61	274.99	286.13
Herbicide	350.18	92.26	277.02	326.62
Hoeing + herbicide	202.3	-149.38	233.3	116.74

4.5.2 Effect of treatments on income ($/ha) for ratoon cane under sprinkler irrigation

Based on cane price in 2014, different treatments fetched different incomes but the control treatment fetched below the break even income in all the varieties (Table 4.5.2). However, the rest of the treatments fetched incomes above the breakeven even though the profit margins were widely different. N21 fetched the highest income in the combination treatment ($554.70/ha) (Table 4.5.2).

Table 4.5.2 Income ($/ha) for ratoon cane under sprinkler irrigation

Gross Margins for Ratoon cane sprinkler irrigated (Income$ /ha)

	Varieties			
Treatments	N19	N23	N21	N27
Control	-112.86	-455.22	-191.68	-248.32
Hoeing	319.92	236.18	553.91	317.46
Herbicide	367.51	286.23	554.7	438.93
Hoeing + herbicide	56.46	24.44	315.08	302.76

4.5.3 Effect of treatments on income ($/ha) for plant cane under flood irrigation

A huge loss ($ -1056.63) was realized in the control treatment of N23. All the other control treatments in other varieties did not fetch above the break even income (Table 4.5.3). Low profit margins were realized in hoeing treatment of N19 variety ($5.23/ha) and in N23 hoeing treatment ($13.91/ha).

Table 5.5.3 Income ($/ha) for plant cane under flood irrigation

Gross Margins for Plant cane flood irrigated (Income$ /ha)

	Varieties			
Treatments	N19	N23	N21	N27
Control	-409.85	-1056.63	-289.57	-390.01
Hoeing	5.230	13.91	303.21	62.76
Herbicide	59.10	94.56	267.66	219.23
Hoeing + herbicide	150.54	-1.00	313.72	250.40

4.5.4 Effect of treatments on Income ($/ha) for ratoon cane under flood irrigation

Based on the price of sugarcane that was paid to farmers in 2014, There was a recovery from a loss in control treatment on N21 in 2013 of $289.57/ha (Table 4.5.3) to a profit of $138.37 /ha (Table 4.5.4). Another recovery was registered in control treatment of N27 variety when it recovered from a loss of $390.01/ha to a profit of $222.11/ha (Table 4.5.4). There was a huge recovery in income as well in N19 Variety in the hoeing treatment when profits moved from $5.23/ha (Table 4.5.3) to $263.69/ha (Table 4.5.4). However there was a drop in the loss in N19 control treatment from $409.85/ha in plant cane to $242.00/ha (Table 4.5.4) in the following year in ratoon cane.

Table 4.5.4 Income ($/ha) for ratoon cane under flood irrigation

Gross Margins for ratoon cane flood irrigated (Income$/ha)

	Varieties			
Treatments	N19	N23	N21	N27
Control	-242	-933.04	138.37	222.11
Hoeing	263.69	265.74	536.67	177.07
Herbicide	413.63	429.08	579.32	360.12
Hoeing + herbicide	87.68	93.41	558.91	359.41

4.6.1 Effect of genotype and environment on plant cane under sprinkler irrigation

From Table 4.6.1, there was no significant interaction between the treatments and varieties on the measured variables. Stalk height, stalk thickness and yield was significantly different amongst the varieties that were exposed to the treatments but the treatments were not significantly different in their influence to the outcome of the measured variables. (Appendix 1).

Table 4.6.1 Mean square, G x E for plant cane under sprinkler irrigation

	df	SH	ST	YD	SUC	BRIX
Var	3	16417.80*	2.14*	448.02*	2.01	0.16
Treat	3	3425.70	1.35	38.87	0.57	1.98
Var X Treat	9	1069.80ns	0.92ns	20.24ns	1.50ns	2.97ns
Residual	48	739.80	0.49	64.96	1.17	2.7
Total	63	21653.10	4.90	572.09	5.25	7.81

*denotes significance at (p= 0.05) and ns = not significant (P> 0.05)

4.6.2 Effect of genotype and environment on ratoon cane under sprinkler irrigation

Stalk height was significantly different in the treatments. There was an interaction in yield obtained to the treatments ($P<0.05$) in the ratoon cane of sprinkler irrigated. Sucrose, brix and stalk thickness was not significantly different ($P>0.05$). Other factors could have been influencing these variables in the experiment.

Table 4.6.2 Mean square, G X E for ratoon cane under sprinkler irrigation

	df	SH	ST	YD	SUC	BRIX
Var	3	5380.00	1.11	1487.8	0.33	0.73
Treat	3	24785.00*	1.38	1592	0.51	0.48
Var X Treat	9	1766.00ns	1.09ns	594.8*	0.32ns	1.42ns
Residual	48	1605.00	2.1	123.4	0.46	1.67
Total	63	33536.00	5.68	3798.00	1.62	4.30

*denotes significance at (p= 0.05) and ns = not significant (P> 0.05)

4.6.3 Effect of genotype and environment on plant cane under flood irrigation

The treatments and variety characteristics influenced the stalk height, yield and sucrose content (Table 4.6.3). There was an interaction between the treatments and variety in the yield obtained. The weed control option and an influence on yield (T/Ha) obtained. There was no interaction in stalk height, stalk thickness, sucrose and brix content.

Table 4.6.3 Mean square, G x E for plant cane under flood irrigation

	df	SH	ST	YD	SUC	BRIX
Var	3	11599.60*	0.93	1667.48*	6.01*	6.86
Treat	3	12585.10*	1.43	1430.64*	3.83	2.01
Var X Treat	9	502.90ns	0.65ns	462.25*	0.51ns	1.13ns
Residual	48	431.90	0.68	48.49	0.90	1.5
Total	63	25119.50	3.69	3608.86	11.25	11.50

*denotes significance at (p= 0.05) and ns = not significant (P> 0.05)

4.6.4 Effect of genotype and environment on ratoon cane under flood irrigation

An interaction was observed in the ratoon cane of flood irrigation on yield. The interaction of method of weed control had an influence on the yield (t/ha) of cane harvested (Table 4.6.4). However, the varieties as well were significantly different in yield obtained in individual subplots Brix, sucrose, stalk height and stalk thickness were not significantly different.

Table 4.6.4 Mean square, GxE for ratoon cane under flood irrigation

	df	SH	ST	YD	SUC	BRIX
Var	3	9512.00	1.4	1023.07*	1.81	2.25ns
Treat	3	12220.00	0.52	764.28*	1.16	2.75ns
Var X Treat	9	217.00	0.74	169.59*	0.62	0.96ns
Residual	48	1268.00	0.77	68.69	0.79	1.56
Total	63	23217.00	3.43	2025.63	4.38	7.52

*denotes significance at (p= 0.05) and ns = not significant (P> 0.05)

4.7 Discussion and interpretation

Plant height is one of the contributing factors to average stalk weight and eventually the yield (t/ha) of sugarcane (Rain, 2000). Weed free crop is subject to better growing conditions due to less inter specific competition as well as fewer attacks by pests which hinder the normal growth of crops (Yadava, 1993). Well adapted varieties to the environment tend to grow faster than less adapted and hence their competitive advantage against weeds (Fauconneir, 1995). This is because weeds compete for growth resources such as water, sunlight, carbon dioxide and even space (Klingman, 1975). Stalk thickness is a major contributing factor to sugarcane yield both in mass and sucrose content. The thicker the stalks are, the higher the stalk mass and hence the higher the yield and vice versa. Sugarcane stalk is the reservoir for sucrose juice and hence the thicker the stalk, the higher the sucrose yield (tons/ha) (Smith,1995).

Sucrose content (Pol% cane) referred to as a pure disaccharide D-glucopyranosyi-D-frucofuranoside, known commonly as sugar (Laboratory manual, 1985). This is a very important parameter that determines the quality of cane to produce sugar. The higher the Pol % cane, the better the quality of cane and hence more sugar to be produced. Brix content is used to indicate the quality of cane as well but it’s an indicator of the Pol% in cane. Sugarcane is a perennial crop that grows in ratoons for 5 to 7 years before replanting (Yadava, 1993). Normally the plant cane yield is lower than the first ratoon (Blackburn, 1984) due to increased tillering from the first ratoon onwards which leads to more stalk population per hectare and hence more yield.

CHAPTER 5

SUMMARY, CONCLUSSION AND RECOMENDATIONS

5.1 SUMMARY

Generally the plots that had a high weed infestation in the control plots achieved shorter average stalk height in all the varieties (Table 4.1.1) in comparison to the plots where some form of weed control was practiced. In the plant cane of sprinkler irrigated, the variety N21 achieved the highest average final stalk height of 255.6 cm (Table 4.1.1) at the age of 12 months in the combination treatment of manual and herbicide weed control option. Relatively tall stalks were observed in other weed control options due to less competition on growth resources between the crop and the weeds. The flood irrigated cane behaved the same as the sprinkler irrigated in the control and as well got shorter cane than other treatments. This was for both in the plant cane and ratoon cane as well (Table 4.4.1). Variations in height between that plant cane and ratoon cane of the same trial could be attributed to the element of crop establishment. Ratoon cane tend to have an early take off after harvesting due to already established rooting system which in turn will act as an advantage in the crop competitive advantage over weed in the ratoon crops (Yadava, 1993).

Perennial weeds such as couch grass and cyperus are a typical problem in sugarcane fields due to their well-established system and network in the environment (Gupta, 2000). Some notable results were observed in the hoeing treatment of flood irrigated

N27 variety. This achieved best height at the age of 12 months of 315.5 cm in hoeing treatment (Table 4.3.1) as compared to the highest height the same variety obtained in the plant cane sprinkler irrigated of 255.6cm (Table 4.1.1). N21 and N27 generally performed very well both in plant cane as well as in ratoon cane of both sprinkler irrigated and flood irrigated.

Thicker stalks are a good measure of a healthy crop and hence higher yield. Considerable stalk thickness was recorded in plots where weeds were controlled which are a sign that presence of weeds hinders normal growth of crops. Control treatments for the sprinkler irrigated plant cane had average stalk thickness less than other treatments. Presence of uncontrolled weeds in the control plots led to massive competition for resources and hence thinner stalks. The sucrose level (Pol % cane) was not all that responsive to stalk thickness since there are other factors that influence this attribute. Basically the stalk thickness of sugarcane was not a big variant because it was observed that for the sprinkler irrigated plant cane, it was not significantly different.

In the ratoon cane, (Table 4.2.2) the stalk thickness once again was not significantly different for varieties such as N19 and N21 in all the treatments .This can lead to a suspicion that rather than being a trait that can be environmentally influenced, it can be mainly genetically influenced. The same trend was witnessed in the ratoon crop of the same treatments in the following year.

Sucrose content (Pol% cane) referred to as a pure disaccharide D-glucopyranosyi-D-frucofuranoside, known commonly as sugar (Laboratory manual, 1985). From Table 4.2.5, the average sucrose levels for varieties N19 variety in all the employed treatments was not significantly different in the ratoon cane sprinkler irrigated despite the fact that the yields were very different across the treatments. This can imply that, weeds presence in the field affect mainly the plant population as well as growth in form of accumulation of dry mass and the sucrose content cannot be directly affected by presence of weeds. According to Yadava, (1993) presence of weeds harbour pests and disease which can affect the growth of cane as well as paving way to some opportunist pests which in turn affect the sucrose quality. The same was observed as well in the N27 variety (Table 4.2.3) Besides the fact that in the control, the weed pressure was high, the sucrose level was not significantly different to the rest of the treatment for the cane that was sampled for sucrose tests which implies that other factors rather than weed pressure contributed to the sucrose level.

Brix content is a measure of total suspended solids in the solution. These solids include the sucrose hence it's a near reflection of what level sucrose content is. It is measured by a refractometer. Brix is determined when a refractometer is equipped with a scale to determine the relationship between refractive indices at 20^0 C and the percentage by mass of total soluble solids of a pure aqueous sucrose solution there by determining the concentration of sucrose containing solution.

For sprinkler irrigated there was no interaction between treatments and varieties on brix content. It appeared as if the brix content is mainly genetically rather than environmentally influenced. Other factors that influence the brix content levels are burn to crush delay, the dry off period, ripening and variety (Sandura, 1998). The more fresh the cane is, the more brix content and hence more sucrose (Yadava, 1993). With ratoon cane, the control plots fetched lower brix content than the rest of the treatments where some form of weed control activities were done (Table 4.2.4). This is mainly that weeds do harbour pests and diseases and with pest damage, some opportunist's fungi and bacterial will go on and attack the crop and hence reducing the brix content (Sundara, 1998).

The results shows that lower yields were obtained in the control plots in all the varieties (Table 4.3.3). This is in agreement with Vrandver, 1997 that weeds led to yield losses in cropping systems and if left unattended can cause total yield loss. This was evidenced in (Table 4.3.3) where variety N23 yielded 12.03t/ha against a potential yield level of 65t/ha for the field. Good yields were produced in all other treatments where yields better compared to potential were evidenced (Table 4.3.3).

In the ratoon of flood irrigated, the results showed that variety N23 was most susceptible to weed pressure as it obtained 6.1t/ha (Table 4.4.3) down from 12.02t/ha in the plant cane (Table 4.3.3). The same scenario was observed in the ratoon crop of sprinkler irrigated where the same variety was badly affected by weeds resulting in yield loses. This could be due to competition induced by weeds for the growth resources (Rijin, 2000). Crops need to be wed free during the very limited number of weeks so that crop productivity is enhanced (Baker, 1991).

The gross margin analysis was carried out for the treatments based on the actual prices for the 2013/14 season. It was calculated based on the cost of activity per manday or per ha of land and being compared to the gross income to calculate the net profit/loss. The results show that losses were fetched in all the control treatment plots where costs were higher than the income (Table 4.5.1). Plots where some form of weed management activities were carried out fetched some profits (Table 4.5.1). This was mainly driven by the costs of production and the yield obtained. Other treatments as well registered some losses (Table 4.5.1) where combination treatment in N23 variety plant cane as well fetched a loss of $149.38/ha. However the herbicide only treatment of N19 variety fetched the highest profit of $350.18/ha (Table 4.5.1). Herbicide treatment in sprinkler irrigation registered increased profit margins from plant cane to ratoon cane. N19 variety gained $17.93/ha, N23 herbicide treatment increased net profit from plant cane (table 4.5.2) to ratoon cane (Table 4.5.2) from $92.26 /ha to 286.23/ha which represents 210% increase.

In the ratoon crop of sprinkler irrigated, control treatment of N23 variety fetched below the break even and registered a loss of $455.22/ha (Table 4.5.2) up from $405.69/ha (Table 4.5.1) in the plant cane due a drop in yield from plant cane to ratoon cane which is not usual. Herbicide only treatment fetched the highest profit margin in N21 variety of $554.70/ha (Table 4.5.2) followed by hoeing treatment with $553.91/ha (Table 4.5.2). The almost similar trend was observed in the flood irrigated trial and the varieties N21 and N27 came out to be doing well. The variations in profit margins were mainly attributed to the cost of activities and effectiveness of weed control to contribute to the yield of the crop.

In the flood irrigated, control of N23 fetched a net loss of $1056.63/ ha and it became the worst of all even though other varieties in the same treatment were below the breakeven. Good profit margins fetched in the combination treatment of N21 variety of $313.71/ha (Table 5.5.3). Generally in all the treatments where some form of weed management activities were carried out, some profits were registered being driven by yields obtained and costs involved. Profit margins of $5.23/ha (Table 5.5.3) to as high as $313.72/ha (Table 5.5.3) Herbicide treatment registered some significant net profit increases in varieties such as N19, N21 and N27. From the results, the herbicide treatment proved to economically viable as evidenced by increases in net profit margins in N19 variety from $59.10/ha in plant cane to $413.63/ha (Table 4.5.4). N23 as well made significant increases in net profit from $94.56/ha (Table 4.5.3) in plant cane to $429.08/ha (Table 4.5.4)

5.2 CONCLUSIONS

Presence of weeds in a sugarcane crop is detrimental to growth of the crop and as well the recommended weed free period should be observed so that weeds don't affect the yield of the crop. Control or no weeding of sugarcane proved to be not ideal in the sugarcane production industry as it performed very poor in all the measured parameters and hence it is concluded that proper weeding and care should be done to sugarcane crop at Mafambisse Estate. The presents of weeds in the sugarcane crop affects the growth as evidenced by shorter cane stalks in control plots and therefore weeds should be removed from the field as soon as the crop is established.

Proper weed control is ideal as this enhance crop performance. Manual weed, herbicide only and combination of manual and herbicide resulted in profits in almost all varieties but higher profit margins were fetched in the herbicide only treatment. Given the soils at Mafambisse , it is concluded that proper application of herbicides in the weed control programme is ideal as it improves the profit margins.

It was also concluded that variety N23 was not ideal for production at Mafambisse soils as it produced very poor yields and eventually losses but varieties N21 and N27 were the best adapted varieties at Mafambisse Estate.

5.3 IMPLICATIONS

Heavy infestations of weeds in sugarcane fields can lead to lower yields as weeds will be competing for growth resources. Improper weed management and infective weed management practices can lead to high costs of production which in turn threatens the viability of the industry. It is pertinent that a more sustainable way of weed management be adopted that effectively controls the weeds below the economic injury level as we as being cost effective and sustainable for the industry. From the research, the herbicide application should be adopted as the principal weed control option and hopefully coupled with some hoeing in association to make sure that weed don't lead to yield losses. The losses due to weed are beyond the direct yield losses due to stress exerted to the crop, but there are some indirect losses such as harvesting inefficiencies, reduced rationing cycle leading to increased plough out rate as well as weeds as alternative hosts to pest and diseases of sugarcane.

5.4 RECOMMENDATIONS

It is therefore recommended that weeds should be controlled before they reach economic injury level which in turn will affect the viability of the enterprise. It is also recommended that herbicide application should be used as the main weed control option given the conditions at Mafambisse Sugar Estate as it was the most effective and as well produced the best profit margins in the recommended varieties. This is evidenced by the results in Table 4.5.2 for sprinkler ratoon cane where herbicide only treatment came out to be the best in profits from all the varieties with hoeing coming second. Table 4.5.1 as well confirmed the same with herbicide only treatment producing the best results in plant cane of sprinkler irrigated cane with hoeing coming second. Food irrigated ratoon cane as well showed the same trend. It is as well recommended that an integrated herbicide programme should be designed which involves the use of both chemical and hoeing weed control options.

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APPENDICES

Appendix 1: Analysis of variance for plant cane sprinkler irrigated height assessment

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treat	3	49253.4	16417.8	22.19	<.001
Var	3	10277.2	3425.7	4.63	0.006
Treat.Var	9	9628.3	1069.8	1.45	0.196
Residual	48	35508.3	739.8		
Total	63	104667.1			

Appendix 2: Analysis of variance for plant cane sprinkler irrigated stalk thickness

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treat	3	6.4219	2.1406	4.33	0.009
Var	3	4.0469	1.3490	2.73	0.054
Treat.Var	9	8.2656	0.9184	1.86	0.082

Residual	48	23.7500	0.4948
Total	63	42.4844	

Appendix 3: Analysis of variance for ratoon cane sprinkler irrigated height assessment

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Treat	3	16140	5380.	3.35	0.027
Var	3	74354.	24785.	15.44	<.001
Treat.Var	9	15898	1766.	1.10	0.382
Residual	46	73860.	1606.		
Total	61	176925.			

Appendix 4: Analysis of variance for ratoon cane sprinkler irrigated stalk thickness assessments

Source of variation	d.f(m.v.)	s.s.	m.s.	v.r.	F pr.
Treat	3	3.339	1.113	0.53	0.663
Var	3	4.130	1.377	0.66	0.583
Treat.Va	9	9.766	1.085	0.52	0.854
Residual	46(2)	96.417	2.096		

Total	61(2)	113.548

Appendix 5: Analysis of variance for plant cane flood irrigated height assessments

Variate: AH13

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treat	3	34798.8	11599.6	26.86	<.001
Var	3	37755.3	12585.1	29.14	<.001
Treat.Var	9	4525.9	502.9	1.16	0.339
Residual	48	20730.2	431.9		
Total	63	97810.2			

Appendix 6: Analysis of variance for plant cane flood irrigated stalk thickness assessments

Variate: AT13

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treat	3	2.7969	0.9323	1.37	0.264
Var	3	4.2969	1.4323	2.10	0.113
Treat.Var	9	5.8906	0.6545	0.96	0.485

Residual	48	32.7500	0.6823
Total	63	45.7344	

Appendix 7: Analysis of variance for ratoon cane flood irrigated final plant height assessments

Variate: AH14

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treat	3	28716.	9572.	7.55	<.001
Var	3	36661.	12220.	9.64	<.001
Treat.Var	9	1956.	217.	0.17	0.996
Residual	48	60868.	1268.		
Total	63	128202.			

Appendix 8: Analysis of variance for ratoon cane flood irrigated final stalk thickness

Variate: AT14

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treat	3	4.1875	1.3958	1.81	0.158
Var	3	1.5625	0.5208	0.68	0.571
Treat.Var	9	6.6875	0.7431	0.96	0.481

Residual	48	37.0000	0.7708
Total	63	49.4375	

Appendix 9: Gross margin for Plant cane sprinkler irrigated Variety N21

	Control	Hoeing	Herbicide	Herb +Hoeing
Average Yield(t/ha)	41	71.4	68.4	72
Gross income @$33.72/ton raw cane	1382.52	2407.61	2306.45	2427.84

Variable costs

1st Ploughing (US$/ha)	150.79	150.79	150.79	150.79
2nd Plough (US$/ha)	75.38	75.38	75.38	75.38
Ridging(USD/ha)	87.19	87.19	87.19	87.19
Planting (US$/ha)	68.57	68.57	68.57	68.57
Fertilizer (US$/ha)	326.94	326.94	326.94	326.94
Fertilizer Application(US$/ha	16	16	16	16

1 st Weeding (US$/ha)	0	66.5	0	66.5
2 nd Weeding(US$/ha)	0	66.5	0	66.5
Irrigation (US$/ha)	637.86	637.86	637.86	637.86
pre-emergent (US$/ha)	0	0	36.83	36.83
Post emergent (US$/ha)	0	0	19.74	19.74
Harvesting (US$/ton)	78.72	137.09	131.33	138.24
Transport (US$)	287	499.8	478.8	504
Total variable cost	1728.45	2132.62	2029.43	2194.54
Net profit/loss	-345.93	274.99	277.02	233.3
Sugarcane price in US$/ton	33.72			
Harvesting / ton	1.92			
Transport /ton	7			
Exchange rate: $/ZAR	10			
Exchange rate: $/MZN	30			

Appendix 10: Gross margin for Plant cane sprinkler irrigated Variety N19

	Control	Hoeing	Herbicide only	Herb +Hoeing
Average Yield(t/ha)	43.9	69.1	70.9	70.3
Gross income @$33.72/ton raw cane	1480.31	2330.05	2390.75	2370.52
Variable costs				

1st Ploughing (US$/ha)	150.79	150.79	150.79	150.79
2nd Plough (US$/ha)	75.38	75.38	75.38	75.38
Ridging(USD/ha)	87.19	87.19	87.19	87.19
Planting (US$/ha)	68.57	68.57	68.57	68.57
Fertilizer (US$/ha)	637.86	637.86	637.86	637.86
Fertilizer Application(US$/ha	16	16	16	16
1 st Weeding (US$/ha)	0	66.5	0	66.5
2 nd Weeding(US$/ha)	0	66.5	0	66.5
Irrigation (US$/ha)	315.78	315.78	315.78	315.78
pre-emergent (US$/ha)	0	0	36.83	36.83
Post emergent (US$/ha)	0	0	19.74	19.74
Harvesting (US$/ton)	73.17	132.67	136.13	134.976
Transport (US$)	307.52	483.7	496.3	492.1
Total costs (US$)	1732.26	2100.942	2040.568	2168.216
Net Profit	-251.952	229.11	350.18	202.30
Sugarcane price in US$/ton	33.72			
Harvesting / ton	1.92			
Transport /ton	7			
Exchange rate: $/ZAR	10			
Exchange rate: $/MZN	30			

Appendix 11: Gross Margin analysis for Plant cane sprinkler irrigated .Variety N27

	Control	Hoeing	Herbicide only	Herb +Hoeing
Average Yield(t/ha)	34.1	69.8	70.4	67.3
Gross income @33.72/ton raw cane	1149.85	2353.66	2373.89	2269.36
Variable costs				
1st Ploughing (US$/ha)	150.79	150.79	150.79	150.79
2nd Plough (US$/ha)	75.38	75.38	75.38	75.38
Ridging(USD/ha)	87.19	87.19	87.19	87.19
Planting (US$/ha)	68.57	68.57	68.57	68.57
Fertilizer (US$/ha)	326.94	326.94	326.94	326.94
Fertilizer Application(US$/ha	16	16	16	16
1 st Weeding (US$/ha)	0	66.5	0	66.5
2 nd Weeding(US$/ha)	0	66.5	0	66.5

Irrigation (US$/ha)	637.86	637.86	637.86	637.86
pre-emergent (US$/ha)	0	0	36.83	36.83
Post emergent (US$/ha)	0	0	19.74	19.74
Harvesting (US$/ton)	65.47	83.2	135.17	129.22
Transport (US$)	238.7	488.6	492.8	471.1
Total variable cost	1666.9	2067.53	2047.27	2152.62
Net profit/loss	-517.05	286.13	326.62	116.74
Sugarcane price in US$/ton	33.72			
Harvesting / ton	1.92			
Transport /ton	7			
Exchange rate: $/ZAR	10			
Exchange rate: $/MZN	30			

Appendix 12: Gross Margin for ratoon cane sprinkle irrigated , variety N21

	Control	Hoeing	Herbicide	Herb +Hoeing
Average Yield(t/ha)	36.2	72.3	68.8	64.9
Gross income @$33.72/ton raw cane	1220.66	2437.96	2319.94	2188.43
Variable costs				
Fertilizer (US$/ha)	428.42	428.42	428.42	428.42
Fertilizer application (US$/ha)	17	17	17	17

1 st Weeding (US$/ha)	0	71.78	0	71.78
2 nd Weeding(US$/ha)	0	71.78	0	71.78
Irrigation (US$/ha)	637.86	637.86	637.86	637.86
pre-emergent (US$/ha)	0	0	36.83	36.83
Post emergent (US$/ha)	0	0	19.74	19.74
Harvesting (US$/ton)	75.66	151.11	143.79	135.64
Transport (US$/ton)	253.4	506.1	481.6	454.3
Total costs (US$)	1412.34	1884.05	1765.24	1873.35
Net Profit	-191.68	553.91	554.7	315.08
Sugarcane price in US$/ton	33.72			
Harvesting / ton	2.09			
Transport /ton	7			
Exchange rate: $/ZAR	10			
Exchange rate: $/MZN	43			
MAP /ton	644.14			
5.1.5 /ton	612.03			
Urea	488.40			

Appendix 13: Gross margin analysis for ratoon cane sprinkler irrigated , Variety 19.

	Control	Hoeing	Herbicide	Herb +Hoeing
Average Yield(t/ha)	39.4	62.8	61.2	54.4
Gross income @$33.72/ton raw cane	1328.57	2117.62	2063.66	1834.37

Variable costs

Fertilizer (US$/ha)	428.42	428.42	428.42	428.42
Fertilizer application (US$/ha)	17	17	17	17
1 st Weeding (US$/ha)	0	71.78	0	71.78
2 nd Weeding(US$/ha)	0	71.78	0	71.78
Irrigation (US$/ha)	637.86	637.86	637.86	637.86
pre-emergent (US$/ha)	0	0	36.83	36.83
Post emergent (US$/ha)	0	0	19.74	19.74
Harvesting (US$/ton)	82.35	131.25	127.91	113.7
Transport (US$/ton)	275.8	439.6	428.4	380.8
Total costs (US$)	1441.426	1797.692	1696.158	1777.906
Net Profit	-112.86	319.92	367.51	56.46
Sugarcane price in US$/ton	33.72			
Harvesting / ton	2.09			
Transport /ton	7			
Exchange rate: $/ZAR	10			
Exchange rate: $/MZN	30			
MAP /ton	644.14			
5.1.5 /ton	612.03			
Urea	488.4			

Appendix 14: Gross margin analysis for ratoon cane sprinkler irrigated , Variety N23

	Control	Hoeing	Herbicide	Herb +Hoeing
Average Yield(t/ha)	25.5	59.4	57.9	53.1
Gross income @$33.72/ton raw cane	859.86	2002.97	1952.39	1790.53

Variable costs				
Fertilizer (US$/ha)	428.42	428.42	428.42	428.42
Fertilizer application (US$/ha)	17	17	17	17
1 st Weeding (US$/ha)	0	71.78	0	71.78
2 nd Weeding(US$/ha)	0	71.78	0	71.78
Irrigation (US$/ha)	637.86	637.86	637.86	637.86
pre-emergent (US$/ha)	0	0	36.83	36.83
Post emergent (US$/ha)	0	0	19.74	19.74
Harvesting (US$/ton)	53.3	124.15	121.01	110.98
Transport (US$/ton)	178.5	415.8	405.3	371.7
Total costs (US$)	1315.08	1766.79	1666.16	1766.09
Net Profit	-455.22	236.18	286.23	24.44
Sugarcane price in US$/ton	33.72			
Harvesting / ton	2.09			
Transport /ton	7			
Exchange rate: $/ZAR	10			

Exchange rate: $/MZN	30
MAP /ton	644.14
5.1.5 /ton	612.03
Urea	488.4

Appendix 15: Gross margin analysis for ratoon cane sprinkler irrigated, Variety N27.

	Control	Hoeing	Herbicide	Herb +Hoeing
Average Yield(t/ha)	33.9	62.7	64.1	64.4
Gross income @$33.72/ton raw cane	1143.11	2114.24	2161.45	2171.57
Variable costs				
Fertilizer (US$/ha)	428.42	428.42	428.42	428.42
Fertilizer application (US$/ha)	17	17	17	17
1 st Weeding (US$/ha)	0	71.78	0	71.78
2 nd Weeding(US$/ha)	0	71.78	0	71.78
Irrigation (US$/ha)	637.86	637.86	637.86	637.86
pre-emergent (US$/ha)	0	0	36.83	36.83
Post emergent (US$/ha)	0	0	19.74	19.74
Harvesting (US$/ton)	70.85	131.04	133.97	134.6
Transport (US$/ton)	237.3	438.9	448.7	450.8

Total costs (US$)	1391.43	1796.78	1722.52	1868.81
Net Profit	-248.32	317.46	438.93	302.76
Sugarcane price in US$/ton	33.72			
Harvesting / ton	2.09			
Transport /ton	7			
Exchange rate: $/ZAR	10			
Exchange rate: $/MZN	43			
MAP /ton	644.14			
5.1.5 /ton	612.03			
Urea	488.4			

Appendix 16: Gross margin analysis for plant cane flood irrigated, Variety N19

	Control	Hoeing	Herbicide	Herb +Hoeing
Average Yield(t/ha)	38.1	60.2	60.5	56.2
Gross income @$33.72/ton raw cane	1284.73	2029.94	2040.06	1895.06
Variable costs				
1st Ploughing (US$/ha)	150.79	150.79	150.79	150.79
2nd Plough (US$/ha)	75.38	75.38	75.38	75.38

Ridging(USD/ha)	87.19	87.19	87.19	87.19
Planting (US$/ha)	68.57	68.57	68.57	68.57
Fertilizer (US$/ha)	326.94	326.94	326.94	326.94
Fertilizer Application(US$/ha	8	8	8	8
1 st Weeding (US$/ha)	0	66.5	0	66.5
2 nd Weeding(US$/ha)	0	66.5	0	66.5
Irrigation (US$/ha)	637.86	637.86	637.86	637.86
pre-emergent (US$/ha)	0	0	36.83	36.83
Post emergent (US$/ha)	0	0	19.74	19.74
Harvesting (US$/ton)	73.15	115.58	116.16	107.9
Transport (US$)	266.7	421.4	423.5	393.4
Total variable cost	1694.582	2024.714	1950.96	2045.604
Net profit/loss	-409.85	5.23	89.1	-150.54
Sugarcane price in US$/ton	33.72			
Harvesting / ton	1.92			
Transport /ton	7			
Exchange rate: $/ZAR	10			
Exchange rate: $/MZN	43			

Appendix 17: Gross margin analysis for ratoon cane flood irrigated , variety N19

	Control	Hoeing	Herbicide	Herb +Hoeing
Average Yield(t/ha)	34.1	61	63.3	57.6
Gross income @$33.72/ton raw cane	1149.85	2056.92	2134.48	1942.27
Variable costs				
Fertilizer (US$/ha)	428.42	428.42	428.42	428.42
Fertilizer application (US$/ha)	17	17	17	17
1 st Weeding (US$/ha)	0	71.78	0	71.78
2 nd Weeding(US$/ha)	0	71.78	0	71.78
Irrigation (US$/ha	637.86	637.86	637.86	637.86
pre-emergent (US$/ha)	0	0	36.83	36.83
Post emergent (US$/ha)	0	0	19.74	19.74
Harvesting (US$/ton)	71.27	127.49	132.3	120.38
Transport (US$/ton)	237.3	438.9	448.7	450.8
Total costs (US$)	1391.85	1793.23	1720.85	1854.59
Net Profit	-242	263.69	413.63	87.68

Sugarcane price in US$/ton	33.72
Harvesting / ton	2.09
Transport /ton	7
Exchange rate: $/ZAR	10
Exchange rate: $/MZN	43
MAP /ton	644.14
5.1.5 /ton	612.03
Urea	488.4

Appendix 18: Gross margin analysis for plant cane flood irrigated, variety N23

	Control	Hoeing	Herbicide only	Herb +Hoeing
Average Yield(t/ha)	12.02	60.55	60.72	62.23
Gross income @$33.72/ton raw cane	405.31	2041.75	2047.48	2098.4
Variable costs				
1st Ploughing (US$/ha)	150.79	150.79	150.79	150.79
2nd Plough (US$/ha)	75.38	75.38	75.38	75.38

Ridging(USD/ha)	87.19	87.19	87.19	87.19
Planting (US$/ha)	68.57	68.57	68.57	68.57
Fertilizer (US$/ha)	326.94	326.94	326.94	326.94
Fertilizer Application(US$/ha	8	8	8	8
1 st Weeding (US$/ha)	0	66.5	0	66.5
2 nd Weeding(US$/ha)	0	66.5	0	66.5
Irrigation (US$/ha)	637.86	637.86	637.86	637.86
pre-emergent (US$/ha)	0	0	36.83	36.83
Post emergent (US$/ha)	0	0	19.74	19.74
Harvesting (US$/ton)	23.08	116.26	116.58	119.48
Transport (US$)	84.14	423.85	425.04	435.61
Total variable cost	1461.95	2027.84	1952.92	2099.39
Net profit/loss	-1056.63	13.91	94.56	-1
Sugarcane price in US$/ton	33.72			
Harvesting / ton	1.92			
Transport /ton	7			
Exchange rate: $/ZAR	10			
Exchange rate: $/MZN	43			

Appendix 19: Gross margin analysis for ratoon cane flood irrigated, variety N23

	Control	Hoeing	Herbicide	Herb +Hoeing
Average Yield(t/ha)	6.1	60.6	63.7	55.9
Gross income @$33.72/ton raw cane	205.69	2043.43	2147.96	1884.95
Fertilizer (US$/ha)	428.42	428.42	428.42	428.42
Fertilizer application (US$/ha)	17	17	17	17
1 st Weeding (US$/ha)	0	71.78	0	71.78
2 nd Weeding(US$/ha)	0	71.78	0	71.78
Irrigation (US$/ha	637.86	637.86	637.86	637.86
pre-emergent (US$/ha)	0	0	36.83	36.83
Post emergent (US$/ha)	0	0	19.74	19.74
Harvesting (US$/ton)	12.75	126.65	133.13	116.83
Transport (US$/ton)	42.7	424.2	445.9	391.3
Total costs (US$)	1138.73	1777.69	1718.88	1791.54
Net Profit	-933.04	265.74	429.08	93.41
Sugarcane price in US$/ton	33.72			
Harvesting / ton	2.09			
Transport /ton	7			
Exchange rate: $/ZAR	10			
Exchange rate: $/MZN	43			
MAP /ton	644.14			

5.1.5 /ton	612.03
Urea	488.4

Appendix 20: Gross margin analysis for plant cane flood irrigated, variety N21

	Control	Hoeing	Herbicide only	Herb +Hoeing
Average Yield(t/ha)	42.95	80.28	67.7	74.92
Gross income @$33.72/ton raw cane	1448.27	2707.04	2282.84	2526.3
Variable costs				
1st Ploughing (US$/ha)	150.79	150.79	150.79	150.79
2nd Plough (US$/ha)	75.38	75.38	75.38	75.38
Ridging(USD/ha)	87.19	87.19	87.19	87.19
Planting (US$/ha)	68.57	68.57	68.57	68.57
Fertilizer (US$/ha)	326.94	326.94	326.94	326.94
Fertilizer	8	8	8	8

Application(US$/ha				
1 st Weeding (US$/ha)	0	66.5	0	66.5
2 nd Weeding(US$/ha)	0	66.5	0	66.5
Irrigation (US$/ha)	637.86	637.86	637.86	637.86
pre-emergent (US$/ha)	0	0	36.83	36.83
Post emergent (US$/ha)	0	0	19.74	19.74
Harvesting (US$/ton)	82.46	154.14	129.98	143.85
Transport (US$)	300.65	561.96	473.9	524.44
Total variable cost	1737.844	2203.8276	2015.184	2212.5864
Net profit/loss	-289.57	503.21	267.66	313.72
Sugarcane price in US$/ton	33.72			
Harvesting / ton	1.92			
Transport /ton	7			
Exchange rate: $/ZAR	10			
Exchange rate: $/MZN	43			

Appendix 21: Gross margin analysis for ratoon cane flood irrigated, variety N21

	Control	Hoeing	Herbicide	Herb +Hoeing
Average Yield(t/ha)	49.6	71.6	69.8	74.8
Gross income @$33.72/ton raw cane	1672.51	2414.35	2353.66	2522.26

Variable costs				
Fertilizer (US$/ha)	428.42	428.42	428.42	428.42
Fertilizer application (US$/ha)	17	17	17	17
1 st Weeding (US$/ha)	0	71.78	0	71.78
2 nd Weeding(US$/ha)	0	71.78	0	71.78
Irrigation (US$/ha	637.86	637.86	637.86	637.86
pre-emergent (US$/ha)	0	0	36.83	36.83
Post emergent (US$/ha)	0	0	19.74	19.74
Harvesting (US$/ton)	103.66	149.64	145.88	156.33
Transport (US$/ton)	347.2	501.2	488.6	523.6
Total costs (US$)	1534.14	1877.68	1774.33	1963.34

Net Profit	138.37	536.67	579.32	558.91
Sugarcane price in US$/ton	33.72			
Harvesting / ton	2.09			
Transport /ton	7			
Exchange rate: $/ZAR	10			
Exchange rate: $/MZN	43			
MAP /ton	644.14			
5.1.5 /ton	612.03			
Urea	488.4			

Appendix 22: Gross margin analysis for plant cane flood irrigated , variety N27

	Control	Hoeing	Herbicide	Herb +Hoeing
Average Yield(t/ha)	38.9	63.85	65.37	71.28
Gross income @$33.72/ton raw cane	1311.71	2153.02	2204.28	2403.56

Variable costs

1st Ploughing (US$/ha)	150.79	150.79	150.79	150.79
2nd Plough (US$/ha)	75.38	75.38	75.38	75.38
Ridging(USD/ha)	87.19	87.19	87.19	87.19
Planting (US$/ha)	68.57	68.57	68.57	68.57

Fertilizer (US$/ha)	326.94	326.94	326.94	326.94
Fertilizer Application(US$/ha	8	8	8	8
1 st Weeding (US$/ha)	0	66.5	0	66.5
2 nd Weeding(US$/ha)	0	66.5	0	66.5
Irrigation (US$/ha)	637.86	637.86	637.86	637.86
pre-emergent (US$/ha)	0	0	36.83	36.83
Post emergent (US$/ha)	0	0	19.74	19.74
Harvesting (US$/ton)	74.688	155.58	116.16	109.9
Transport (US$)	272.3	446.95	457.59	498.96
Total variable cost	1701.718	2090.26	1985.05	2153.16
Net profit/loss	-390.01	62.76	219.23	250.4
Sugarcane price in US$/ton	33.72			
Harvesting / ton	1.92			
Transport /ton	7			
Exchange rate: $/ZAR	10			
Exchange rate: $/MZN	43			

Appendix 23: Gross margin analysis for ratoon cane flood irrigated , variety N27

	Control	Hoeing	Herbicide	Herb +Hoeing

Average Yield(t/ha)	53	57	60.9	66.7
Gross income @$33.72/ton raw cane	1787.16	1922.04	2053.55	2249.12
Variable costs				
Fertilizer (US$/ha)	428.42	428.42	428.42	428.42
Fertilizer application (US$/ha)	17	17	17	17
1 st Weeding (US$/ha)	0	71.78	0	71.78
2 nd Weeding(US$/ha)	0	71.78	0	71.78
Irrigation (US$/ha	637.86	637.86	637.86	637.86
pre-emergent (US$/ha)	0	0	36.83	36.83
Post emergent (US$/ha)	0	0	19.74	19.74
Harvesting (US$/ton)	110.77	119.13	127.28	139.4
Transport (US$/ton)	371	399	426.3	466.9
Total costs (US$)	1565.05	1744.97	1693.43	1889.71
Net Profit	222.11	177.07	360.12	359.41
Sugarcane price in US$/ton	33.72			
Harvesting / ton	2.09			
Transport /ton	7			
Exchange rate: $/ZAR	10			
Exchange rate: $/MZN	43			
MAP /ton	644.14			

5.1.5 /ton	612.03
Urea	488.4