THE EFFECT OF PLANT MEDIA AND INTRA-ROW SPACING USING BUD CHIP TECHNOLOGY ON GROWTH AND YIELD OF SUGARCANE (*SACCHARUM OFFICINARUM* L) VARIETIES.

By

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A Research Project submitted in Partial fulfilment of requirements for a Bachelor of Science Agronomy Honours Degree.

DEPARTMENT OF AGRONOMY

MIDLANDS STATE UNIVERSITY

NOVEMBER 2016

DECLARATION

I hereby declare that the whole work submitted as Thesis entitled "**Effect of plant media and intra row spacing using Bud chip technology on growth and yield of sugarcane (*Saccharum officinarum* L) varieties.**" for the degree of BSc Agronomy Honours is the results of my own investigation.

SAMUEL MASUKUME ...……………………… ……/……/……….

Student Reg #: R132676F **Signature of Student** **Date**

CERTIFICATION OF THESIS WORK

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

Effect of plant media and intra row spacing using Bud chip technology on growth and yield of sugarcane (*Saccharum officinarum* L) varieties.

That the dissertation is acceptable in form and content, that satisfactory knowledge of the field covered by the dissertation was demonstrated by the candidate through oral examination held on **19/10/2016**.

SUPERVISOR: MR M. CHANDIPOSHA

SIGNATURE: ………………………… **Date**:.…/……/……

ABSTRACT

The experiments were conducted at Zimbabwe Sugar Association Experiment Station, Chiredzi, Zimbabwe during the period 2015-2016 to study the growth, yield and economic benefit analysis of sugarcane as influenced by plant media, intra-row spacing and varieties. Two experiments were conducted with the 1st experiment that evaluated the best plant media to raise sugarcane bud chips and the 2nd experiment on determining the best intra-row spacing that gives best yield, using different sugarcane varieties.

Effect of plant media and variety experiment was arranged in a 4*2 factorial design in Randomised Complete Block Design (RCBD) replicated three times, with four plant medium (Composted filter cake, Composted pine bark, Composted cattle manure and Top soil mix) and two varieties (ZN7 and ZN10). Data was analysed using GenStat 14th edition and separation of means was done using LSD at ($P<0.05$). Analysis of variance revealed that emergence % was significantly ($P<0.05$) affected by the main effects of varieties and types of plant growth media. There was interaction ($P<0.05$) of treatments affected plant height at 6 WAP, shoot dry weight, root dry weight and total biomass accumulated at 6 WAP. The study generally showed that ZN10 is a fast growing variety and Composted filter cake is the most suitable plant media that can be used for raising sugarcane bud chips. Therefore, to produce sturdier speedlings, Composted filter cake can be used by farmers when propagating bud chip of varieties ZN10 and ZN7. Moreover, further study need to explore and determine mixing ratio for Composted pine bark and Composted filter cake as well as the use of plant growth promoters to enhance bud emergence and growth of speedlings in the nursery.

Effect of intra-row spacing and variety on growth, yield and economic benefit analysis of plant cane raises through Bud chip technology was done in 2015-16 cropping season. The experiment was a6*2 factorial in RCBD with two varieties (ZN10 and ZN7) and six intra-row spacing (Double row planting of three eyes setts, 0.3 m bud chip speedlings, 0.5 m bud chip speedlings, 0.7 m bud chip speedlings, 0.9 m bud chip speedlings and 0.5 m single eyed speedlings) replicated three times.All intra-row spacings were comparably the same with regards to plant height with the exception of 0.9 m which recorded the least plant height (26WAP). Double row planting of setts recorded the highest tiller peak on tiller population ha^{-1}which was significantly different from all other treatments (14 WAP) followed by normalization to optimum shoot population for all treatments with the exception of 0.9 m bud chip speedlings which failed to reach the normal plant population. The results indicate that 0.7 m bud chip speedling and 0.9 m bud chip speedling was superior to any other treatments with respect to tiller population per stool, leaf nitrogen content % and cash income (return per dollar and new income generated from saving in seed) and the values reduced with decreasing intra-row spacing. Significantly highest number of millable stalks per ha was recorded in conventional double row planting of three eyed setts and reduced progressively with an increase in intra-row spacing. Results revealed that sugarcane had the capacity to compensate on cane and sugar yield under various intra-row spacing and varieties, thereby resulting in comparable yield values ($P<0.05$).Sugarcane farmers are recommended to use an intra-row spacing of 0.9 m when using bud chips speedlings so as it compensate on yield, therefore more revenue from high cane yield ha^{-1}, sugar yieldha^{-1} and income realised from saving in seed material is realised. Varieties ZN7 and ZN10 can be used when propagating sugarcane from bud chip speedlings as they compensate under different intra-row spacings to give the same final cane and sugar yield. Further investigations are required to determine the progressive ratoon growth of sugarcane crop established through bud chip speedling so as to determine its feasibility. Innovation on mechanical planting of speedlings may be done to on human labour requirements during planting.

DEDICATION

I dedicate this piece of work to my beloved parents (Lameck and Lorrain Masukume) and to all my brothers.

ACKNOWLEDGEMENTS

All praise are due to the Almighty God for giving me sound health and energy to complete the present research work and prepare this thesis for the Bachelor of Science Agronomy Honours Degree.

With great pleasure, I would like to express my profound sense of gratitude, to my academic research supervisor Mr. M. Chandiposha, Midlands State University for his constant guidance, active supervision, timely and solitary instructions and constructive criticism, throughout the period of research work and in preparing this thesis.

The author thankfully acknowledges the Zimbabwe Sugar Association Experiment Station (ZSAES) for awarding funding for the study. The author extends his thanks and sincere appreciation to Dr M. Nzima, Director of ZSAES, for his active co-operation during this research work. In this research work, innovation, cooperative suggestions, active supervision and execution, generous help and affectionate encouragement from Mr. S. Chinorumba, ZSAES Agronomist and Mr. C. Nyati, ZSAES Agronomist and all Research Officers is greatly acknowledged. Mr. B. Simango, is thanked for assistance in the fabrication of the sugarcane bud chipper.

Finally, I express pleasure to extend extreme gratitude and appreciation to my parents (Lameck Masukume and Lorrain Masukume), my brothers (Justin, Donald, Collen and Talent), and friends (Ellen Moyo, Mazviita Marufu and Blessing Mthadwa) for their encouragement an unreserved help during the period of this work and in thesis preparation.

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Acronym

AN	Ammonium Nitrate
DAC	Direct Analysis of Cane
DAP	Days after planting
DAT	Days after transplanting
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
LAI	Leaf Area Index
SSI	Sustainable Sugarcane Initiative
TVD	Top Visible Dewlap
WAP	Weeks after Planting
ZSAES	Zimbabwe Sugar Association Experiment Station

CHAPTER ONE

INTRODUCTION AND JUSTIFICATION

Sugarcane (*Saccharum officinarum L)* is a tropical cereal crop of the Graminae family that is grown under irrigation in the South Eastern Lowveld area (Chiredzi, Hippo valley, Triangle, Mkwasine and Chisumbanje) (Chandiposha, 2013). Sugarcane is used mainly in the production of sugar, and the by-products molasses and bagasse are used as raw materials in the distillery, animal feed processing industries and cogeneration of electricity. Socioeconomically, the sugarcane industry employs over 25 000 people (Scoones, 2014) and in 2005 it contributed 95% and 1.4% respectively to the Gross Domestic Product (GDP) of Masvingo Province and entire the Zimbabwe (Annual Action Program, 2009).

In sugarcane production, seedcane used for planting is the prime factor to establish a good initial crop stand and it accounts 20% of the total production cost (Galal, 2016). Traditionally in Zimbabwe, sugarcane is grown using stem cuttings called setts which are short cane stalks with one or more buds. In this system, depending on the variety used (Nyati, 1998), very high sugarcane seed rate of 7-10 tonnes ha^{-1} are used so as to compensate poor sprouting of bud owing to damage done during mechanical handling (Orgeron, 2003) and stalk rot diseases. High seed rate is due to the use of double row planting system in which the three eyed setts are planted parallel along the furrow. The use of large number of three eyed setts per furrow result in a very strong competition among the main shoots, which in turn reduces the number of tillers per planting material used (Verma, 2004). Moreover, the conventional use of three eyed setts impose high cost to the estate and growers resulting in shortage of planting material to cover annually planted commercial fields problem in transportation, handling as well as storage of seed material. The use of high planting rates also forces an increase in the acreage of seed cane which competes for fertile land (Netsanet et al; 2014) that would have been for the production of cane crop for milling.

One alternative method to reduce the cost of seed cane and improve seed quality is the use sugarcane bud chip technology. The bud chip technology as a principle in the Sustainable Sugarcane Initiative, involves use of less seed, less water and optimum utilization of and land to achieve more yields (Biksham et al, 2011). The bud chip technology involves excision of sugarcane bud with small material of the root band, germinating them in plant media and finally transplanting the raised speedlings into the main field at determined inter and intra-row plant spacing. Work carried out by Nyati (1998), using single eyed raised speedlings revealed a reduction in seed requirements by considerably 70%. Only ±1 ton ha^{-1} of seedcane (±250 kg ha^{-1} bud chips) is required and also a saving in cost being realised due to the value of the extra cane made available for milling. Moreover, the technology was found to increase cane yield by 11 percent (Hunsigi, 2001).

Depending on the season, it might take 35-70 days respectively in summer and winter (Clowes and Breakwell, 1998) for the speedlings to be transplanted into the main field. In the Sustainable Sugarcane Initiative (SSI), with spacing (1.5 m * 0.6 m) only 13 500 buds/ha of single buds are used to achieve 122 500 - 137 500 millable cane/ha (Goud, 2011). Trials conducted by Nyati (1998) at ZSAES, using single eyed setts revealed that intra-row spacing ranging from 0.5 to 0.75 m and inter-row spacing of 1.5 m can be used during transplanting. Hence when using the Bud Chip technology, wide intra-row space between individual plants, thus promoting a great scope of air and sunlight to enter the plant canopy, results in more tillering, improved photosynthetic activity causing an increase in length and stalk diameter. Therefore this research serves to come up with a variety and standard intra-row plant spacing/ planting density that can be adopted by sugarcane grower so as to attain high returns while maximising on seed cane material.

However, suitable plant media is a prerequisite in raising of bud chips. Research done in India Sugarcane Research Institute revealed that sawdust, coco-pith (Radha, 2011) and vermin-compost (Biksham et al, 2011) can be used to achieve desired bud emergence and subsequent growth in the nursey. These plant media types are not readily available in low veld area, so there is need to investigate on the scope of different ready available plant media such as pine bark, filter cake, ZSAES media mix and cattle manure in their possibilities to support bud growth. At ZSAES, a soil mix of top soil, sand and manure (5:2:2) by volume is being used for raising single eyed setts. The use of soil as potting media is not gaining ground, as it causes land degradation and in addition, soil mixes are difficult to standardize because field soils are inconsistent, difficult to sterilize, heavy to ship and might contain residual herbicides that might affect emergence and growth of plants (Kessler, 2004). Composted filter cake is a residue left from the treatment of sugar cane juice by filtration that is a rich source nutrition that can be an alternative plant media to raise bud chips. Some trials conducted in Brazil have indicated that filter cake mixed with bagasse can be used as a plant media in the production of citrus seedlings (Prado et al; 2013), thus it has a scope of being used in raising bud chips. Clowes and Breakwell (1998), asserts that composted bagasse has been used at ZSAES for raising speedlings. However, of late, bagasse is currently being used for electricity co-generation, making it unavailable for growers.

In the Zimbabwe sugar industry, there is limited information available with regards to use of bud chips as source of seed and in particular, the type of plant media, variety and intra-row spacing to adopt when raising speedlings to transplant into the main field.

1.1.0 Main Objective

1.1.1 To evaluate the effect of different growth media and intra- row spacing of the bud chip technology on growth, yield and economic benefits in sugarcane production.

Experiment 1: Effect of plant media and variety on emergence and growth of speedlings raised from sugarcane bud chips.

1.2.0 Objective:

1.2.1 To determine the effect of growth media and variety using bud chip on (sugarcane bud emergence %, shoot length, shoot, root and total accumulated dry weight).

1.3.0 Hypotheses:

1.3.1 Type of growth media and variety has significant effect on bud emergence %, shoot length, shoot dry weight, root dry weight and total shoot dry weight of sugarcane speedlings raised from bud chip.

Experiment 2: Effect of intra row spacing using Bud chip technology on growth and yield of sugarcane (*Saccharum officinarum* L) varieties.

1.4.0 Specific Objectives:

1.4.1 To determine the effect of intra-row spacing on sugarcane growth parameters (stalk height, tiller population ha^{-1}, leaf nitrogen % content and number of tillers per stool and stalk diameter) of sugarcane varieties grown using bud chip technology.

1.4.2 To determine the effect of intra row spacing on sugarcane yield parameters (mean stalk weight, number of millable stalks ha^{-1}, cane yield ha^{-1} and sugar yield ha^{-1}) of sugarcane varieties grown using bud chip technology.

1.4.3 To evaluate the return per dollar and new income gained from using bud chips in sugarcane production.

1.5.0 Hypotheses:

1.5.1 There are significant differences on the effects of intra-row spacing on sugarcane growth parameters (stalk height, tiller population ha^{-1}, leaf nitrogen % content and number of tillers per stool and stalk diameter) of sugarcane varieties grown using bud chip technology.

1.5.2 There are significant differences on the effects of intra-row spacing on sugarcane growth parameters yield parameters (mean stalk weight, number of millable stalks ha^{-1}, cane yield ha^{-1} and sugar yield ha^{-1}) of sugarcane varieties grown using bud chip technology.

1.5.3 The effect of intra row has a significant associated return per dollar and new income gained from sugarcane grown using bud chips.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin and distribution of sugarcane

Sugarcane (*Saccharum officinarum L)* is a C_4 cereal grass crop of the Gramineae family originated from Papua New Guinea and Indonesia about 4000 years ago (Orego, 2008). Sugarcane is generally a large, perennial, tropical or subtropical grass that evolved under conditions of high sunlight, temperatures and large quantities of water and it grows well in the tropical areas between 35^o North and South of the equator (Blume, 1985). In Zimbabwe sugarcane production is confined to the Lowveld area in Chiredzi and Chisumbanje.

2.2 Economic importance of Sugarcane.

Sugarcane is mainly grown for its desired characteristic of accumulating sucrose in its stem which serves as an important source of food, sweetening agents, alcoholic beverages, cosmetics and spirits and bio-energy (Escalona, 2005; Moore, et al, 2013; Agrochart, 2014; Salman, 2014). Bagasse, solid waste stalk material that is left after crushing and extraction of the sugar is dried and used as a fuel (Harris, et al; 1998) and as raw material in the paper industry and in co-generation of power at Triangle and Hippo Valley mills. Cackett, (1998), asserts that Triangle and Hippo Valley mills are self-sufficient with respect to energy requirements as steam from their bagasse fired boilers is used to generate up to 36 megawatts of electricity. Internationally sugarcane is on the second position in the top 25 staple crops, in order by total calories produced by that crop, based on FAO, (2009) and it contributes 75% of the total calories required for 10 billion persons in the world. Sugarcane contributes, about 60% of the total world sugar requirement while the remaining 40% comes from sugar beet (Onwuene, et al, 1993). In Zimbabwe the sugar industry employs approximately 25 000 people directly and it has also contributed 95% and 1.4% respectively to the Gross Domestic Product (GDP) of Masvingo Province and entire Zimbabwe (Annual Action Program, 2009).

2.3.0 Challenges of sugarcane production in Zimbabwe.

The Zimbabwe sugar industry faces daunting problems in meeting its potential production capacity due to factors that limit such as weed, pest and disease incidences, recurrent drought, crop nutrition and handling of seed material. Diseases and pest such as sugarcane smut and *Eldana saccharina* (Mabveni, 2006) have had a significant impact on the sugarcane production as they can cause a yield reduction of over 15 %. On the other hand, proceedings from ZSAES by Chinorumba et al, (2012) revealed that Shamva (*Rottboellia cochinchinensis), Comelina benghalensis* as well as Witchweed (*Striga spp*) are some of the problematic weeds around the sugarcane production areas. Moreover, losses in excess of 40% have been recorded in NCo376, a susceptible variety owing to sugarcane smut (*Ustilago scitaminae*) which limit yield by the reduction of millable stalks. Nutrient management of nitrogen, phosphorus and potassium is also an area of major concern due to leaching of nitrogen as well as salinity problems.

Additionally, sugarcane is planted using three eyed setts in which an average of 8-10 tons ha^{-1} is required (Nyati, 1998). Seedcane used for replanting it being the prime factor to establish a good initial crop stand, it accounts 20% of the total production cost (Galal, 2016), thus transportation of bulk seed stalk material and handling of the bulk material contribute to this cost. In line with technological advancement, and sustainability, the Bud chip technology and tissue culture technique are some of the instrumentalities that are being employed to deal with the handling and reduction in the amount of seed material requirements ha^{-1}.

2.4.0 The Bud Chip Technology sugarcane propagation system.

The bud chip technology is one of the six principles of the Sustainable Sugarcane Initiative (SSI) package brought about by the WWF- ICRISAT project, aimed at departing from the conventional sugarcane cultivation into use of less seed, wide spacing, intercropping, reduction of water use and reduction of chemical inputs in the sugarcane industry (Biksham, et al, 2011). The most important aspect of the SSI is the use of the bud chip raised transplants instead of normal planting of three eyed setts. The sugarcane physiologist, VanDellewijn, (1952) noted that a small volume of tissue and a single root primordial adhering to the bud are enough to ensure full sprouting of the sugarcane bud chips. This then lead to the commercialization on the use of bud chips after the fabrication of the 1st sugarcane bud chipper at Andhra Sugar, (Biksham, et al, 2011). The bud chipper is used to scoop out buds from the stalk, which are later planted in plant media in trays and raised in the nursery for 40 days (Tamil-selvan, 2006), depending on season. The raised speedlings are later transplanted into the main field at definite inter-row and intra-row spacing (1.5 m * 0.6 m) (Biksham, et al, 2011) which facilitates availability of abundant solar radiation and soil aeration that enhance high level of tillering (Srivastava, et al, 2011).

2.4.1 Advantages of the Bud Chip Technology

In the conventional system of three eyed setts, the bulk material imposes hardships in transportation and handling of seed setts, resulting in rapid deterioration, loss of bud viability and subsequently poor germination. Thus the use of bud chips has an advantage of reducing transport cost of seed material due to 97% (Iqbal, et al, 2002; Galal, 2016; Ashok, et al, 2012) reduced weight of the seed material (Galal, 2016; Khalidi, et al, 2013). Use of bud chips also maximizes on seed quality as reduced quantities (50kg ha^{-1}) of seed material is easy to handle and treat effectively with fungicides (Galal, 2016) owing to effective permeation of the solution.Prasad and Sreenivasan, (1996), at Sugarcane Breeding Institute reported that, the use of the bud chip technology as a low cost method facilitated exchange of sugarcane germplasm, in carton boxes across countries for varietal development. This is because of easy storage of bud chips in polyethylene bags after fungicide treatment at low temperature conditions (<10°C) and research has shown about 80% success rate in bud germination after 10 days of storage than buds stored at room temperature (about 40%).

2.4.2 Significant of the bud in sugarcane propagation.

A bud is an embryonic shoot connected to the node and to the root band of the node that contains primordial also consisting of a miniature stem with small leaves, the outer ones having the form of scales. In seed cane production, the bud is the most important delicate part of the stem and it develops into a plumule and the primordial develop to become the primary root that anchors the primary shoot. According to Singh and Gurpreet, (2015), a small volume of tissue and a single root primordial adhering to the bud are enough to ensure germination of the bud. Chandra, et al, (2010), also stated that were growing conditions are favorable, stalk cutting with only one viable bud, performs well as seed material. To kick start germination, the bud gets the nutrition through the function of the invertase enzyme which breakdown sett stored sucrose to glucose for energy. Thus the viability of the bud is important as it determines the initial crop stand and its subsequent growth.

2.4.3 Sugarcane bud germination and establishment

Germination is the activation and the subsequent sprouting of the vegetative buds and it is a function of endogenous and exogenous (VanDellewijn, 1952) factor like cane age, cultivar, optimum temperature, moisture in the sett and in the soil, sett hormonal balance and the rate at which reducing sugars are released within setts. When a sett or bud chip is placed in a moist soil at the right temperature, the bud will shoot, and sett roots will sprout from the root band. Documentation by Julien, (2001) revealed that the sett roots supply the young shoot and roots with water and nutrients for eight to twelve weeks until roots are produced from the base of the developing shoot. During the process of germination high temperatures and humidity levels are required, thus 32-35°C and 85-90% respectively and it is influenced by the plant media on which the buds have been grown.

2.5.0 Effect of different plant medium on growth of sugarcane buds

2.5.1 Top soil mix

One of the factors that influence the success of raising bud chip settlings is the type of plant media composition used (Budi, 2016). Although soil is sometimes incorporated in both commercial and homemade potting mixes, it is considered to be unsuitable potting medium to use for raising seeds. Soil mixtures have been used as potting medium for sugarcane settlings with a mixture of soil, sand and farm yard organic manure/press mud, mixed in the proportion of 1:1:1 (Nijalingappa, 2014). Results by Budi, (2016), review that soil, compost and sand (1:1:1) combination can be used in raising single bud chip settling in the nursery because it has high moisture retention capacity, improved physical (aeration and drainage), chemical (CEC) and biological characteristics. At ZSAES a ratio of 2:2:5 respectively of sand, composted cattle manure and top soil has been use to raise single eyed setts as well as fuzz seedling. However, Kessler, (2004), documented that soil or garden loam comes with a range of problems because their nutrient constituent is inconsistent and can contain spores of micro-organisms such as fungi and bacteria that cause plant diseases. On the other hand, soil can harbor pests, weed seeds and plant debris which might exhibit functional allelopathy for example *Sorghum halepense* which has shown inhibitory effect on sprouting of sugarcane buds. Research carried out by Hasanuzzaman, (2015), revealed that the quality of cattle manure is a function of the pasture on which the animals have been fed on. Manure from cattle fed on a pasture with Johnson grass (*Sorghum Halepense*) has shown to have an inhibitory effect on root and shoot growth of sugarcane due to exhibited functional allelopathy of the root and shoot parts of the grass.

2.5.2 Composted pine bark

Composted pine bark has been recognized as predominant potting media for raising seedlings in the horticultural industry. Nurseries in Zimbabwe, South Africa and Australia have used composted organic matter such as pine bark as a substrate, as it has proved to be the best suitable substrate although it is not the most cost-effective media as it`s availability is limited

(Whicomb, et al, 2007) and only confined to area were pine trees are produced. Pine bark has been extensively used to raise nursery seedlings of horticultural crops such as tomatoes, onions, cabbages and lettuce as well as other field crops like tobacco. In a bid to find the best substrate to use, a lot of research work has been carried out in evaluating the feasibility and potential of using pine bark with different amendments in production of seedlings. In a trial carried out at Kutsaga Research Station, Masaka, et al; (2007) alluded that the use of pine bark remain the best substrate for the production of tobacco seedlings in Zimbabwe and abroad. This owe to the physical and chemical characteristics of pine bark, which promote and support seed/bud germination and subsequent growth into a seedling. Krewer and Ruter, (2012), stated that milled pine bark proves to be a successful media substrate as it has 40-45% and 40% of the internal and inter particular pores spaces respectively, which increase water retention, drainage, reduced air space and water holding porosity. Krewer and Ruter, (2012), results showed that, milled pine bark 0.6 to 9.5mm in diameter is a good potting and has high cation exchange capacity of 10-13 milliequivalents per 100 cubic centimeters high organic matter composition, low initial nutrient that promote plant growth. Physical properties like drainage, are influenced by the friability of the medium of which aeration is one of the most important limiting factors for development of plant roots system, growth and yield of crops.

However, aged pine bark is preferred as it contains less leachable organic acids (Robbins, 2015), and small particles have a larger surface area which improves on water and nutrient holding capacity thus providing high cation exchange capacity. Pine bark has the potential to increase moisture retention and available water content but on the other hand large particle sizes promote aeration on the expense of water retention (Krewer and Ruter, 2012).

2.5.3 Composted filter cake

Filter cake is a product of precipitated sediments and sludge contained in the cane juice and clarification process respectively, after removal by filtration of crushed cane. Cakes of varying moisture are formed and they contain much colloidal organic matter that has high cation exchange capacity. Filter cake has been used in the sugar industry for soil amendments as well as nursery plant media in forestry. This soil-less mixture is typically lightweight, weed and disease free. Alexander, (2005), did a research using fresh and composted filter cake and the results did show a variance of 33%, 14%, 5% and 23% for P, N, K and Ca, respectively between the two medium owing too reduction in carbon concentration in composted filter cake. Composted filter cake was more effective in increasing cane yield per hectare than the fresh filter cake (Korndorfer, et al, 1999), and it contain high levels of organic matter, phosphorus, nitrogen and calcium and contain considerable levels of potassium, magnesium and micronutrients. According to Santos, et al, (2014), phosphorus increases root growth, thus promoting the absorption of water and other nutrients.

Thus, composted filter cake can serve as a good source of organic matter (Bokhtiar et al, 2007) and an alternative source of crop nutrient and soil ameliorant (Razzaq, 2001). Alleoni, et al. (1995), reported that, organic matter in filter cake increases the water retention capacity of the soil because it is hygroscopic and able to retain water up to six times its own weight. This enables composted filter cake to be able to sustain transplants when moisture is limiting. Rangaraj et al. (2007) and Elsayed et al. (2008), reported that yields of various crops including maize and millet showed substantial increase when press mud was applied, and that was attributed to the improved biological, physical and chemical conditions of the soil brought about by the in cooperation of filter cake. Stoffella, et al, (2003), revealed that Composted filter cake was a successfully amendment for raising citrus seedlings.

2.5.4 Composted cattle manure

This is organic matter or waste derived from excreted cattle droppings that has gone under successive decomposition and is used as a source of organic fertilizer in agriculture. Composted cattle manure can increase crop yields by providing large inputs of nutrient and organic material required for plant growth. On the other hand manure produces humic acids which stimulate germination and growth of the seedlings. Research by Khattab, et al, (2015), revealed that highest concentration (60ml/100 L water) significantly increased the plant height, number of leaves, number of branches, reduced the days to flowering stage as well as increased the essential oil percentage in *Carum carvi L*. fruits. Manure can increase crop yields by providing large inputs of nutrients and organic material. Full decomposition of manure is more important because many of the nutrients in the manure are tied up in the organic fraction and must go through a decomposition process to be converted to the inorganic forms available for plant uptake (Unknown, 2000).

However, when the speedlings have been raised in the nursery, they are then transplanted in the main field at definite inter-row and intra-row spacing. Inter-row spacing for sugarcane has been well researched by many scholars and average of 1.2-1.5m has been recommended in sugarcane production as according to Nyati, (1998). Moreover, there is limited information available with regards to intra-row spacing and its effect on growth and yield of speedlings from bud chip grown under Zimbabwean conditions.

2.6.0 Effect of intra-row spacing and variety on growth of sugarcane.

2.6.1.1 The effect of intra-row spacing on shoot height of sugarcane.

The production of sugarcane is influenced by many factors with which plant population and spacing plays an important role in enhancing its productivity (Babaji, et al, 2012). Stalk height is the irreversible vertical growth of the cane stalk. Stalk height and weight are the contributing factors of cane yield and there are a number of factor that influence stalk height which are, plant density, nutrient availability, moisture as well as light. Research work by

Abuzar, et al, (2011) and Sangoi (2001), confirms that the use of high plant populations increases inter plant competition for light, water and nutrients which is detrimental to plant growth as it increases apical dominance thus resulting in increased stalk height (2-3 m) under normal growing conditions (Bull, 2000; Mashiqaa, et al, 2011). In sweet sorghum production, increasing plant density from 40 000 up to 70 000 plants per acre produced a depressed sweet sorghum growth as well as juice quality traits, while stalk length increases with dense sowing (Mahmoud, et al, 2013).

2.6.1.2 The effect of intra-row spacing and variety on tiller population ha^{-1} and number of tillers per stool of sugarcane.

Plant spacing which is a function of inter-row and intra-row spacing, is an important agronomic attribute in crop production, as it has effects on photosynthetically active radiation (PAR), temperature, nutrition, available moisture and plant density within the crop environment (Mashiqaa, et al., 2011). Therefore, proper intra-row plant spacing gives the right plant density which has a direct relationship to tiller production (Ibeawuchi, et al, 2008). Tillering is a phenomenon characteristic through which shoots sprout from the base of grass plant. In sugarcane production, profitability of the crop depends primarily on the tillers produced that will dictate the final number of harvestable stalks hence cane yield (Mastuoka et al, 2012). Thus, the use of wider intra-row plant spacing promote more tiller emergence and survival, reducing the detrimental effects of tiller mortality (Mashiqaa, et al, 2011), that result from increased degree of inter-dependence and intra-plant competition for light, nutrition, space and moisture under narrow intra-row spacing.

Research work by Vasantha, et al, (2014), revealed, that tiller mortality 60-120 days after planting increased with plant density, recording 38%, 33% and 28% respectively for high, normal and low plant density, with varieties Co 98013 and Co 91010 having high and the least tiller mortality respectively. Imam, et al, (1988), confirmed high (48%) and minimum

(32) tiller mortality under the spacing of 90 cm * 45 cm and 120 cm * 120 cm respectively. Imam, et al, (1988), evaluated forty five day old transplanted settlings, variety Isd 16 on two inter row spacing (90 cm and 120cm) and intra row spacing (45, 60, 75, 90, 105 and 120 cm) on growth and yield. Results showed that tiller population, millable stalk population and mean stalk weight per plant were higher at low density planting (120 cm* 120 cm). Significantly higher number of tillers (201 000 per ha) and millable stalks (105 000 per ha) were obtained from high planting density (90 cm* 45 cm) while minimum tillers and millable stalks respectively 109 000 per ha and 74 000 per ha were recorded from low density planting (120 cm* 120 cm). However this indicates that the efficient solar energy utilization as well as higher rate of photosynthates is achieved under wider spacing.

When transplanted bud chip settlings, were used by Budi, (2016), results revealed that the number of tillers which emerged were much more owing to the capacity of each stool to produce 10-20 tillers with 8-10 perfect tillers that grow to final harvest due to high shoot multiplication ration which was worked out to be 1:40 against 1:10 for conventional use of three eyed setts. This is because tillering and tiller senescence are sensitive to light competition and are driven by the state of the existing canopy. Singh, et al; (2001) documented that increasing seed rate decreased the number of tillers per plant and average cane weight while increasing millable canes per hectare, tiller mortality as well as final cane yield. Among plant characters associated with yield, population of stalks at harvest and tillering showed the highest correlation Rahman, et al, (1987).

2.6.1.3 The effect of intra-row spacing on stalk diameter of sugarcane.

Stalk diameter is a transverse measurement of the cane stalk that is done at harvesting. Cane yield it being a function of stalk population at harvest, thickness, weight and height, there is a positive correlation between stalk diameter and height. Research work by Raskar et al, (2003) at Rahuri reported that in plant cane and 1st ratoon, cane girth, number of millable cane per clump and average cane weight were significantly higher at 90 cm intra-row spacing compared to 30 cm and 60 cm intra-row spacing (Rahman, 2012). Mahmoud, et al, (2013), revealed that increasing plant density from 40 000 up to 70 000 plants per ha significantly decreases sweet sorghum growth traits in terms of leaf area and stalk diameter 23.09 % and 10.67 % respectively in the plant crop. Such effect might have been due to inter plant competition for light and mineral nutrients (Abo El-Wafa, et al, 2001; Mahmoud, et al, 1999 and Mokadem, 1994).

2.6.1.4 The effect of intra-row spacing and variety on total number of millable cane of sugarcane.

Cane yield is a function of total number of millable cane as well as stalk weight and height. Thus the number of the final millable cane is dependent on the genetic ability and stability of a variety to tiller and maintain those tillers up to harvesting. Research work by Netsanet, et al, (2014) at Wonji-Shoa showed no significant effect of intra-row spacing on number of millable cane. This proves the elasticity of sugarcane in producing tillers that compensate on available space. Wiedenfeld, (2003) concluded that when reduced planting rates (1.5 m inter-row spacing * single row) were used in commercial sugarcane fields, no reduction in final shoot count was realized compared to the growers` standard planting rates, thus using substantially high seed rate (1.5 m inter-row spacing * double row) is not necessary to attainment of maximum crop stand. However, Netsanet, et al, (2014) reported a significant effect of intra-row spacing in Finchaa owing to moulding which check on further tillering (Sundara, 2000).

2.6.1.5 The effect of intra-row spacing on stalk weight of sugarcane.

This is the relative mass of the sugarcane stalk. Cane yield is determined by the weight of the harvested stalks, thus maintaining a sufficient the number of mother plants per unit area is considered to be an important factor for obtaining higher millable cane stalks as well as higher cane yield. Plant density exerts a strong influence on sugarcane growth, because of its competitive effect on vegetative growth and sugar yield. It has also been reported by many workers that plant population density followed by individual cane weight in sugarcane is positively correlated with cane yield in the subtropical areas (Bull and Bull, 2000). A study on intra-row spacing of setts by Netsanet, et al, (2014), revealed that the effect of intra-row spacing on stalk weight was not significant in plant crop and 1st ratoon. These results are in parity with findings by Tsehay, (1993), who reported no difference in cane weight among five intra-row spacing (10 cm overlapping, 5 cm overlapping, end to end, 5 and 10 cm between setts spacing). The cane height, millable canes and number of internodes did not differ significantly by intra-row spacing but cane girth and per cane weight increased significantly at wider intra-row spacing of 90 cm (Raskar, et al, 2003). Intra row spacing modifies plant architecture, photosynthetic competence of leaves and dry matter partitioning in the stalk (Hussain, et al, 2012).

2.6.1.6 The effect of intra-row spacing and variety on cane tons ha^{-1} of sugarcane.

Bell et al. (2005) carried out an experiment on row configuration and showed that high density planting did not produce more cane or sugar yield at harvest than low density planting. Thus the results revealed that sugarcane possesses the capacity to compansate for different plant configurations and planting densities through variation in stalk number and individual stalk weight. On the other hand, varietal differences with regard to cane yield were noted as evidenced by different growth patterns in response to different inter and intra-row plant spacing. Research by Netsanet, et al (2014) using five intra-row spacing of setts (10cm between setts, 5 cm between setts, setts placed end to end, setts placed ear to ear with 5 cm overlap and setts placed ear to ear with 10 cm overlap), confirms that the cane yield obtained from the widely and densely spaced planting were in statistical parity, and this is similar to previous studies by Tsehay, (1993); Worku, (2001) and Netsanet, et al, (2014). This means that low density planting compensate for the low stalk population owing to the presence of abundant space, sufficient PAR which promoted high photoassimilates production and partitioning of dry matter during heavy tillering in wider spaced planting, thereby avoiding diversion of complex carbohydrate away from the stalks. Where sunlight intensity and quality is limiting, cane yield reduction can be due to the diversion of photosynthates away from the primary stalks, thus it is for this reason that high density planting is practiced in some regions (Nayamuth et al; 2003). The main aim in increasing plant density is to increase crop yield per unit area but research has shown that yield per plant tend to decrease even if yield per unit area remains maintained. This show the compensatory capacity of sugarcane in maintaining yield regardless of spacing. This is because total light interception by the canopy is maximized on increased leaf area index and total yield is increased (Muhammed, et al, 2002). However, according to Bull et al, (2000), the concept of high density planting can increase sugarcane yield by 20-60 tons of cane per hectare. The highest cane yield (89 t ha^{-1}) was obtained with closer spacing of 90 cm * 45 cm while the lowest yield (70 t ha^{-1}) was from the widest spacing of 120 cm * 120 cm (Imam, et al; 1988).

2.6.1.7 The effect of intra-row spacing and variety on sugar yield of sugarcane.

Sugar yield is a finction of cane yield and recoverable sucrose %, thus the total number of millable stalks ha^{-1} and average stalk weight as influenced by plant density plays and pivotal role n determining sugar yield. Mahmoud, et al, (2013) and Netsanet, et al, (2014), revealed that sucrose percent cane was affected only by the main effect of variety and these results corroborates that of Sundara, (2003), who reported that intra-row sett spacing did not affect sucrose content (Tsehay, 1993). Generally, it could be concluded that the reduction in some quality traits (brix %, sucrose, juice extraction %) under close intra-row spacing could be compensated by higher yield of stalks, cane thickness and consequently the final syrup and sugar yields could be increased (Hossain, et al, 2005). On the other hand, Gutte, et al, (2008), documented that plant density of 74 000 plants per ha (45*30 cm spacing) produced higher total sugar by 11.78% and commercial cane sugar by 4.78% and this is at parity with the findings by Matin, et al, (1989), who stated that sugar yield was found 8% more when using single transplanted settlings compared to conventional planting of setts.

2.6.1.8 The effect of intra-row spacing and variety on economics benefit of sugarcane.

For successful adoption of a new technology, economic advantage is the major criterion that all farmers aim at achieving. Rahman, et al, (2012), indicated that the comparative performance of transplanted sugarcane compared to conventional under growers' conditions were estimated that the highest gross return (USD 932.44 ha^{-1}) and gross margin (USD 668.19 ha^{-1}) were obtained respectively. These results are at parity with those of Rahman, et al, (1994) who indicated that the total cost of cultivation of transplanted speedlings cane was about USD 274.89 whereas it was USD 303.46 in conventional cane. Lowest cost in transplanted speedling cane was mainly due to saving of seed materials.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of experimental site.

The experiment was conducted at Zimbabwe Sugar Association Experiment Station (ZSAES), Chiredzi, Zimbabwe. ZSAES is located South East Lowveld of Zimbabwe in Natural Region V, 420m above sea level and at latitude of 21º02`S and longitude of 31º37`E. An average annual rainfall of 625mm falling mainly in the hot summer months (October-March) is received. The area experiences mean, maximum daily temperature of +30°C and a mean, minimum daily temperature between 6-9ºC as shown in Figure 3.1. Evaporation can reach 8-9mm per day during high ambient temperature conditions (Clowes, 1998).

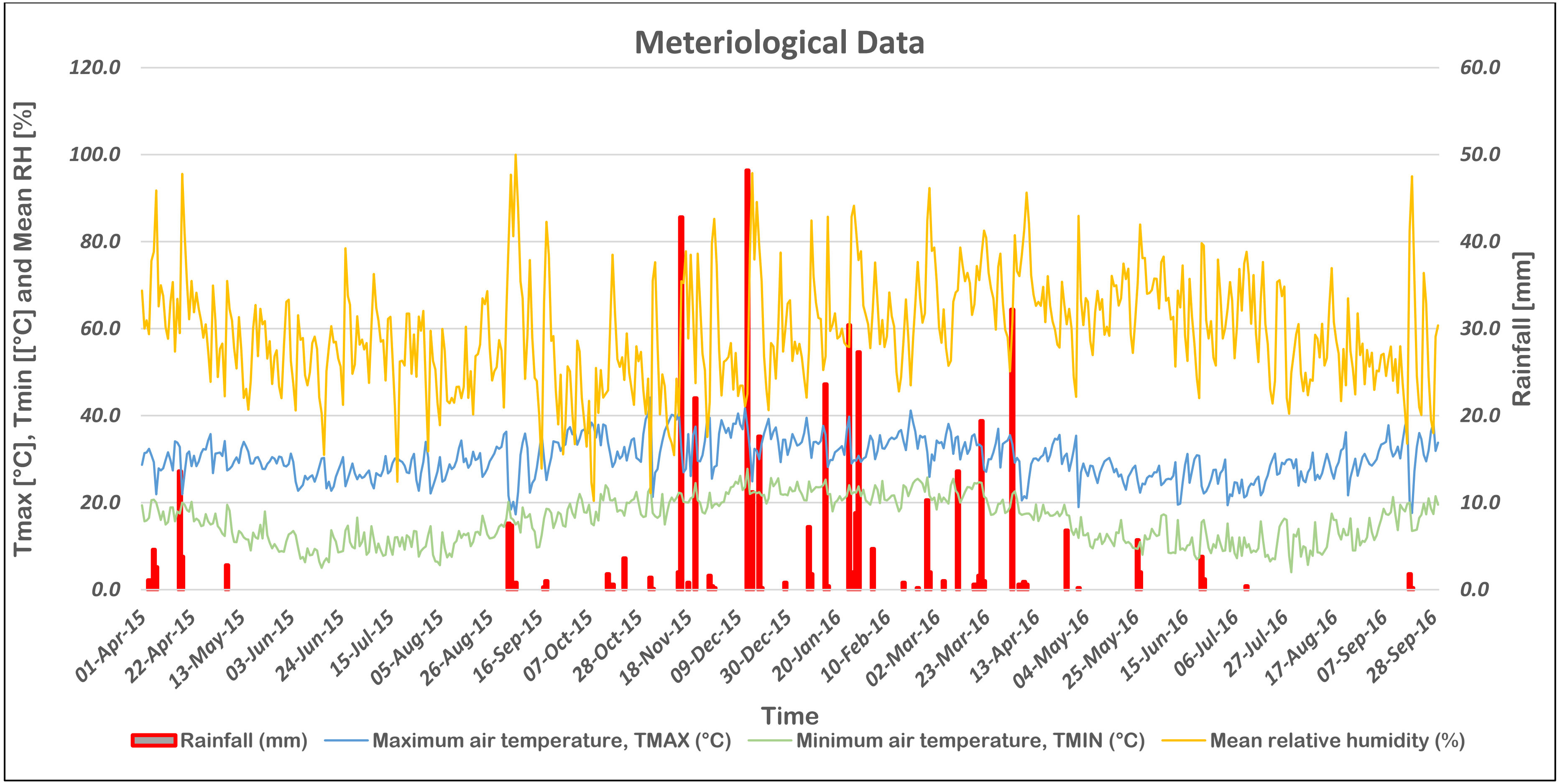

Figure 3.1. Meteorological data showing the daily maximum and minimum temperature (°C), rainfall (mm) and mean relative humidity as from 01-April 2015 to 28 September 2016.

3.2.0 Experiment 1. Effect of plant media and variety on emergence and growth of speedlings raised from sugarcane bud chips.

3.2.1 Experimental design and treatments

The experiment was laid in a 4*2 factorial experiment arranged in Randomized Complete Block Design (RCRD) replicated 3 times. The first factor was plant media; Top soil mix, Composted pine bark, Composted filter cake and Composted cattle manure. The second factor was variety; ZN10 and ZN7 as shown in Table 3.1.

Table 3.1 Treatment combinations of plant media and variety.

	Varieties	
Plant media	ZN7	ZN19
Top soil (55.6%): Sand (22.2%): Manure (22.2%)	T1	T5
Composted pine bark (6-8mm)	T2	T6
Composted filter cake (100%)	T3	T7
Composted cattle manure.	T4	T8

3.2.2 Varieties used.

Sugarcane varieties ZN7 and ZN10 were used for the experiment 1 and 2. ZN10 is an all year harvested variety with cane stalk population of 144 000 stalks/ha, susceptible to lodging, resistant to smut and has low sucrose when early harvested. ZN7 is an all year harvest variety, with cane stalk yield of 88 000 stalk/ha. ZN7 is highly susceptible to Ratoon Stunting Disease (RSD), resistant to smut, susceptible to lodging uniform stalk height and self-trashing (Anon, 2005)

3.2.3 Plant media analysis results.

Plant media samples of 100g were prepared for analysis. Chemical analysis for pH, electrical conductivity, P_2O_5, K, Ca, Mg Na using the CaCl scale, conductivity meter, resin method and atomic adsorption respectively was done (Table 3.2).

Table 3.2 Plant media analysis by measuring pH (CaCl method), electrical conductivity (microS/cm: conductivity meter), P_2O_5 (ppm, resin extract), Potassium, Calcium, Magnesium and Sodium (milli equivalent %; Atomic Adsorption).

Thresh-holds	*5.5-8.5*	*<1000*	*<45*	*<0.35*	-	-	-
Treatments	**pH**	**EC**	**P_2O_5**	**K**	**Ca**	**Mg**	**Na**
	-	**microS/cm**	**ppm**	**me%**	**me%**	**me%**	**me%**
Composted Cattle Manure	7.9	4	383	14	20	11	3.6
Composted filter cake	5.8	1407	631	7.6	17	6	0.4
Top soil mix	6.7	856	398	6.7	9.4	4.3	0.4
Composted pine bark	6.2	93	111	1.2	26	6.5	0.1

3.2.4 Preparation of the bud chips for planting.

Single budded chips were selected from certified 8 months old seed canes (Nyati, 1998), which had good inter-node length (15-18 cm) and girth by simply observing and avoiding canes with disease infestation like fungus growth and spots. Stalks were cut, thrashed and the sugarcane bud chipper was used to excise buds from the stalks. Jesey fluid 10% was used as a disinfectant to dip the blade of the bud chipper to control RSD. Buds were collected in a gunny bag ready for cold treatment with Shavit (1 ml/1L of water) for 5 minutes before planting.

3.3.1 Experimental procedure.

The plant media per treatment were mixed in the percentages shown on the Table 3.1. Twenty litre buckets with drain plugs were three quarter filled with pine bark, filter cake and manure and water was added full beam. The media was pre-water soaked for 12hrs and afterwards the plugs were removed to drain out water. The media was ready for use and taken for planting. Polystyrene trays with 84 cells each shaped like an inverted pyramid measuring 50*50*100mm with a hole in the bottom for drainage were used for planting. Jesey (10%) was used to disinfect the trays prior to planting. Each cell was firstly half filled with the growth media as per treatment and the buds were placed in a slightly slanting position facing upwards and was covered completely with the growth media. Watering was done after planting. Later the trays were then placed on the concrete platform and covered with a black polythene sheet for 7 days as a sheath and removed afterwards to increase temperature and humidity as ambient temperature was low Figure 3.1. Irrigation was be done once per day in the first two weeks (8:00 am) and increased to two times a day (8:00 am and 4:00 pm) 14 DAP. The speedlings were fertilised with Hoagland solution (Jones, 2004), 1L/tray on a weekly interval up to 35 DAP. Frequent scouting for pests and diseases was done. Yellow aphid were observed and were controlled using Dimethioate at 1ml per 1L of water.

3.4.0 Data collection

3.4.1 Emergence percentage.

Bud emergence percentage was done from day 9 up to day 23 Days After Planting (DAP). This involved counting the number of buds that appeared daily and then computing the values in relation to total number planted.

$$\text{Emergence \%} = \frac{\text{Number of buds that have emerged}}{\text{Total number of buds planted}} \text{x } 100$$

3.4.2 Shoot length.

The same computed random numbers were used to select 10 speedlings per tray three and six weeks after 50% bud emergence from all trays. Tape measure will be used to measure plant height from the root band to the TVD leaf of the speedling. A thin wooden stick was inserted into the media up until it reached the bud chip material. Measurements were taken from the root band to the leaf showing the T.V.D. The mean values were recorded.

3.4.3 Shoot, root and total dry weight

At week 5, all the speedlings in the trays were uprooted and the media attached to the roots was washed off using water. Shoots and roots were separated using a razor blade while discarding the bud chip material. The shoots and root samples were oven dried for 72 hours at 105ºC later left to cool and weighed separately using an electronic scale. Total dry weight was calculated as a summation of the shoot and root weights per tray.

3.5.0 Data analysis

Two-way analysis of variance was done using GenStat 14th edition. Data on counts was transformed using the square root method $\sqrt{(x+0.5)}$. Separation of means was carried out using Fisher`s Protected Least Significant Difference ($P<0.05$).

3.6.0 Expt. 2. Effect of intra row spacing using Bud chip technology on growth and yield of sugarcane (*Saccharum officinarum* L) varieties.

3.6.1 Experimental design and treatments

Experiment was laid in a 6*2 factorial experiment arranged in Randomized Complete Block Design (RCRD) replicated 3 times. The first factor was intra-row spacing and second factor being variety as shown in Table 3.3.

Table 3.3 Treatment combinations for intra-row spacing and variety.

	Varieties	
Intra-row plant spacing (m)	ZN7	ZN19
Double row planting of three eyed setts (Control)	T1	T7
0.3 m Bud chip speedlings	T2	T8
0.5 m Bud chip speedlings	T3	T9
0.7 m Bud chip speedlings	T4	T10
0.9 m Bud chip speedlings	T5	T11
0.5 m (single eyed setts)	T6	T12

3.7.0 Trial management

3.7.1 Nursery management of speedlings in the nursery.

The sugarcane bud chip and single eyed setts of ZN7 and ZN10 of a 7 months certified seed cane, were chipped off/ cut using a sugarcane bud chipper and cutting machetes. A total of 1260 (ZN7 bud chips), 1680 (ZN10 bud chips), 420 (ZN7 single eyed setts) and 504 (ZN10 single eyed setts) were planted in trays (84 holes per tray) filled with Composted pine bark medium (6-8mm). The trays were covered with a transparent plastic in a gothic form, for only 6 days after planting to reduce water loss from the medium by creating a humid microclimate. The speedlings were raised in the nursery for 8 weeks, being fertilized with Hoagland solution at weekly intervals 2 weeks after 50% emergence and later transplanted into the main field. Dimethioate was sprayed at 1ml/1litre of water to control Yellow sugarcane aphids.

3.7.2 Agronomic procedure

3.7.2.1 Land preparation

Pre-discing, ripping, discing and row making was done using a 250hp tractor. In the study, 12 plots within 3 blocks were made in a total area of 2754 m^2, gross plot of 32 m^2 (4rows*8m), 504 m^2 discard area and 1.5 m pathway between blocks. Plots were pre-irrigated, 2 days prior to planting and marking of intra-row planting station (50 mm deep) at 0.3 m, 0.5 m, 0.7 m and 0.9 m was done using rouging holes and a pre-marker string.

3.7.2.2 Planting/Transplanting

A total of 20 stalks*4 bundles respectively for ZN7 and ZN10 of certified seedcane (9 months age) was cut with each plot being allocated 20 stalks*2 bundles. Jesey fluid 10% was used to disinfect the machetes during cutting and the cut 3 eyed setts were dipped in Shavit (1ml/1Litre of water) to control Smut. Three eyed setts were planted using the conventional double row planting system and covered with approximately 8-10 mm of soil. Speedlings were also planted one per planting station as according to treatments, firmed into the ground and covered with 5 mm soil layer, just to leave the shoot above the ground. Dead speedlings were replaced by freshly healthy speedlings from the trays within 15 Days After Transplanting (DAT).

3.7.2.3 Fertilization and irrigation

Phosphorus and potassium fertilizers were not applied because soil analysis results show that their levels were above the thresholds of 45 ppm and 0.35 meq respectively. Urea was hand applied in three splits of 1/3 at a rate of 140kg N/ha at 5, 10 and 13WAP. Irrigation was done using the standard irrigation practice as according to Nyati, (1998).

3.7.2.4 Weed, pest and disease management

Dimethioate was applied at a rate of 1ml/1L of water to control Yellow sugarcane aphids on transplants. Soon after pre-irrigation, Acetochlor (2L/ha), Metribuzin at (2L/ha), Actril DS at 1L/ha was sprayed as a pre-emergence, early post and spot spray respectively herbicide for the control of grasses and broad leaf weeds.

3.8.0 Data collection

3.8.1 Stalk height

Four stalks within the three-metre positions were tagged two months after planting. White tags tied on each of the four selected stalk. Wooden pegs were nailed adjacent to individual stalks to determine fixed bases on which measurements were taken up to the TVD using a tape measure and data was recorded.

3.8.2 Average number of tillers per ha and tiller per stool.

Four randomly selected stools were tagged in the 4.5 m^2 area and physical counting of shoots (tiller + stalks) per stool were done at monthly intervals on the tagged stools. All tillers emerging within two month from planting were counted and recorded for each plot to determine percent tiller emergence up-to when tiller number become constant. Numbers of tillers/ha were extrapolated to a hectare for each plot to give the total tiller population/ha. Dead tillers were not counted.

3.8.3 Leaf nitrogen % determination

Leaf samples were collected from 48 stools at 22 weeks after planting and were oven dried at 80°C for 24 hours before milling with a Willey Mill (standard model number 3). Dried leaves were ground to powder and sieved using a 1 mm sieve. Total N was determined using Truspec, Carbon/Nitrogen (C/N) Determinator (Leco Corporation, 2008). The sample of 200 mg was put in a tin foil and combusted in a furnace. The total N after the removal of oxygen and other impurities was measured using a thermal conductivity cell.

3.8.4 Total number of millable cane.

Physical count of millable stalks cane (>0.5 m height) in the 3 m quad was done at harvest (405 DAP) and the results will be recorded.

3.8.5 Average stalk diameter.

Stalk diameter was measured using a Vernier calliper. The measurements were taken from the five selected stalks. Measurements were taken from the middle stalk inter-node at harvesting and an average diameter was calculated by dividing total stalk diameter of sample by the total number of stalks per sample.

3.8.6 Average stalk weight

Twenty four stalks randomly selected, were cut, weighed using an electronic balance and the yield was recorded and expressed in kg/stalk at harvesting. Mean stalk weight was calculated.

3.8.7 Cane yield

All the cane plants in the net plots of 6 m^2 were harvested and all the cane was weighed using a digital Crane scale. The recorded values were extrapolated to a hectare.

3.8.8 Sugar yield (tons ha^{-1})

Recoverable sucrose % was determined as according to methodology by Spencer and Meade (1945) and the sugar yield (tons ha^{-1}) was calculated using the formula:

$$\text{Recoverable sucrose (\%)} = \frac{\text{Cane yield t/ha} * \text{Recoverable sucrose}}{100}$$

3.8.9 Cost Benefit

The cost benefit was calculated based on the different intra-row spacing by multiplying the total yield per hectare by the producer price ($), then subtracting the total production cost as per treatment. Return per dollar invested was calculated

$$\text{Return per dollar} = \frac{\text{Gross income}}{\text{New cost}}$$

3.9.0 Data analysis

Two-way analysis of variance was done using GenStat 14th edition. Separation of means was carried out using Fisher`s Protected Least Significant Difference ($P<0.05$).

CHAPTER FOUR

RESULTS

Experiment1. Effect of plant media and varieties on emergence and growth of speedlings raised from sugarcane bud chips.

4.1.0 Bud Emergence %

The analysis of variance indicated that bud emergence % was significantly affected by plant media and variety but not by the interaction of the factors as shown in Appendix 1.

4.1.1 Effect of different plant media on bud emergence % 23 DAP.

The results revealed that across the assement period, there were significant differences (P<0.05) between different plant media on the mean bud emergence %. Mean bud emergence % for Top soil mix and Composted cattle manure were not statistically different from 9-16 DAP as shown in 4.1. Composted pine bark had the highest final bud emergence % followed by Composted filter cake with Composted cattle manure recording the least final mean bud emergence % 23 DAP.

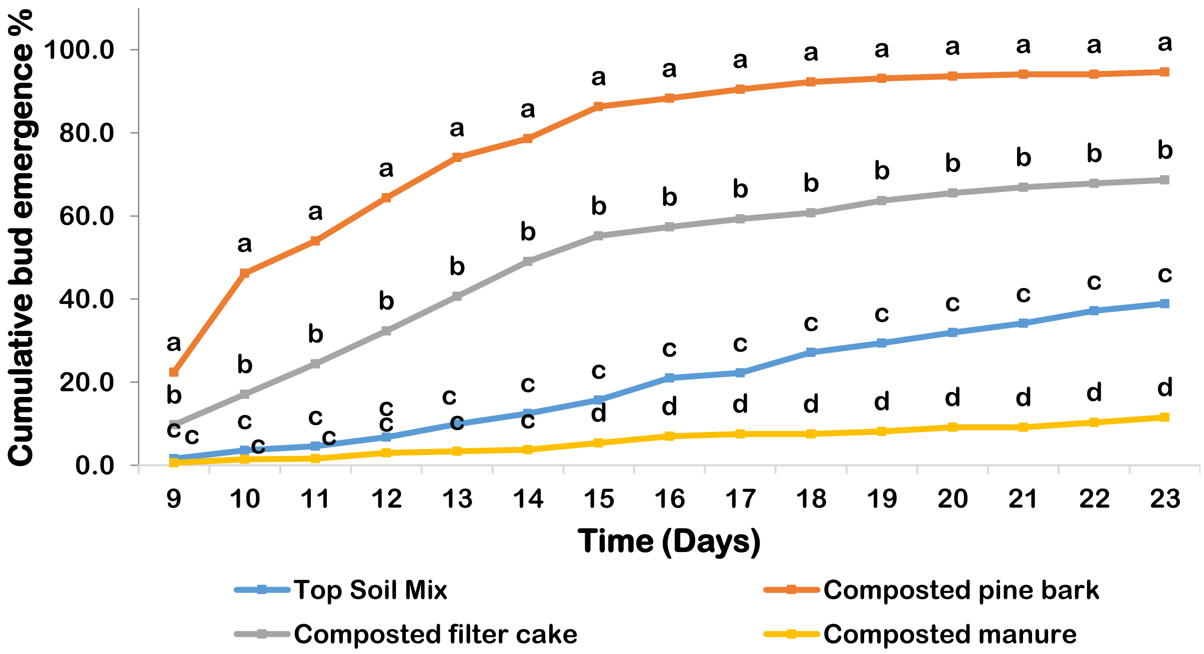

Figure 4.1. Effect of different plant media on bud emergence

4.1.2 Effect of variety on bud emergence % from 9-23 DAP.

Generally, across the assessment period, ZN10 had a higher bud emergence % as compared ZN7 as shown in Figure 4.2. Initially at 9 DAP, mean rate of bud emergence between varieties ZN7 and ZN10 was low and not significantly different ($P<0.05$) as shown in 4.2. The progression from 10-23 DAP showed significant differences with an abrupt increase in bud emergence for ZN10 and ZN7 respectively from 9-16 and 9-15 DAP.

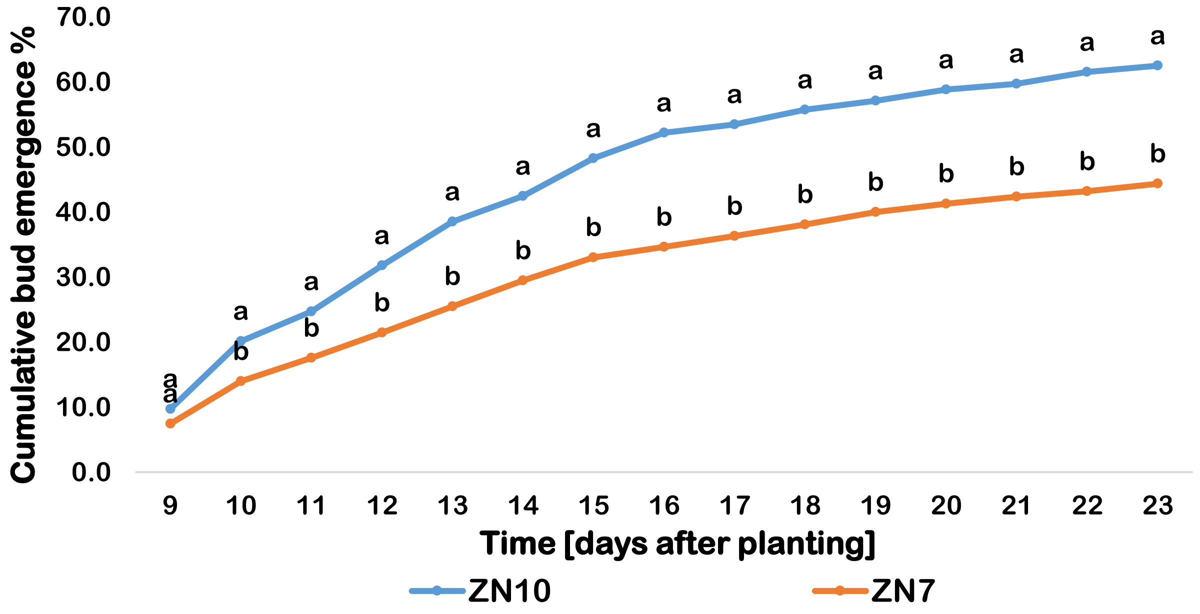

Figure 4.2. Effect of sugarcane varieties on bud emergence as assessed from 9 to 23 days after planting.

4.1.3 Effect of plant media and variety on shoot height per speedling (mm).

There was an interaction ($P<0.05$) between plant media and variety on shoot height at 6 WAP as shown on Figure 4.3.3. At variety ZN10, Composted filter cake, Composted pine bark and Top soil mix recorded the highest shoot height which was not statistically significant while at variety ZN7, Composted filter cake recorded the highest shoot height which was not statistically different from Composted pine bark but significantly different from Top soil mix and Composted manure. Composted manure recorded the least value (mean square root height +0.5) which was not significantly different both at variety ZN7 and ZN10.

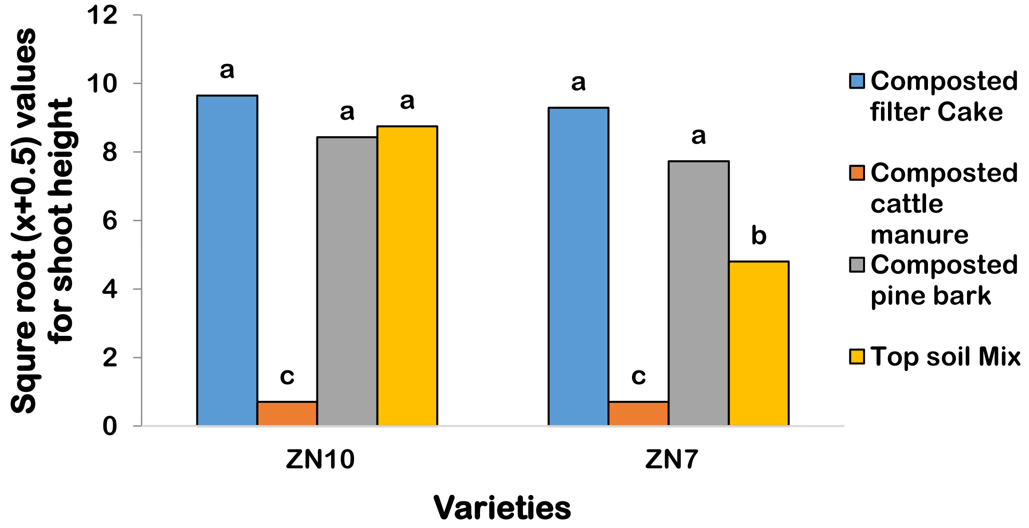

Figure 4.3. Means of square root transformed values (x+0.5) for shoot height (mm) per speedling at 6 WAP.

4.1.4 Effect of different types of plant medium on shoot dry weight per speedling.

There was an interaction ($P<0.05$; Appendix 4) between plant media types and varieties on shoot dry weights per speedling as shown in 4.4. Composted filter cake recorded the highest shoot dry weight value which was highly significant from all treatment combinations as shown in Figure 4.44.4. At variety ZN10, mean values for Composted cattle manure and Top soil mix were not significantly different while at variety ZN7, Composted cattle manure and Top soil mix were significantly different with Composted manure recoding the least mean square root shoot dry weight value.

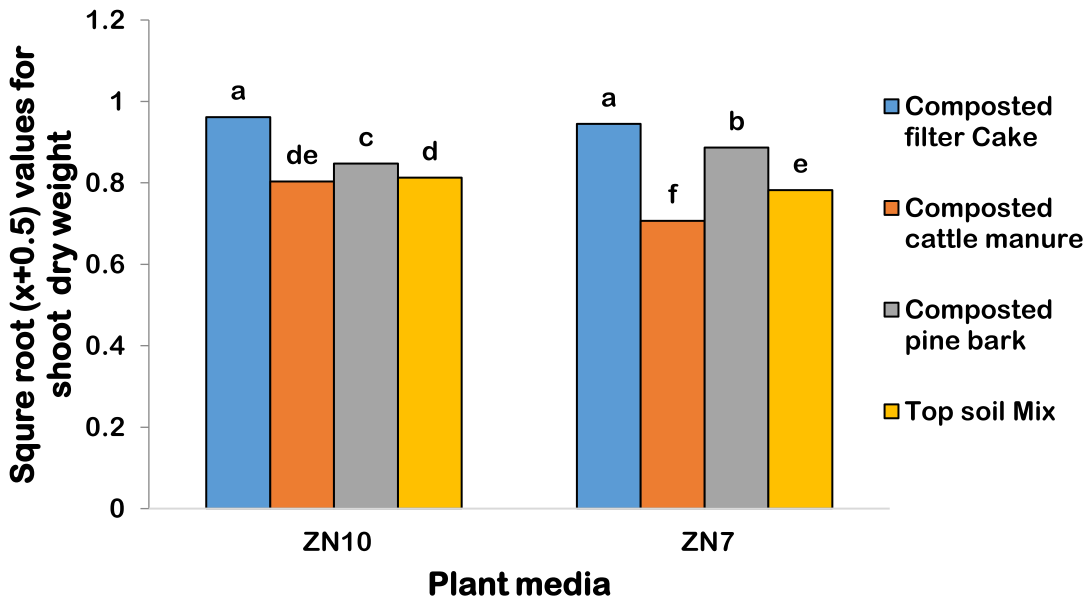

Figure 4.4. Means of square root transformed (x+0.5) values for shoot dry weight (g) 6 WAP.

4.1.5 Effect of different types of plant media on dry root weights.

There was interaction ($P<0.05$) between plant media and variety of sugarcane on square root values of dry root weights. At variety ZN7, Composted pine bark recorded the highest mean square root value for dry root weight which was not statistically different from ZN10 in Composted filter cake and ZN10 in Composted pine bark as shown in Figure 4.54.5. ZN10 and ZN7 in Composted cattle manure and Top soil mix respectively recorded the least mean square root values for root dry weights which were not statistically different ($P=0.05$).

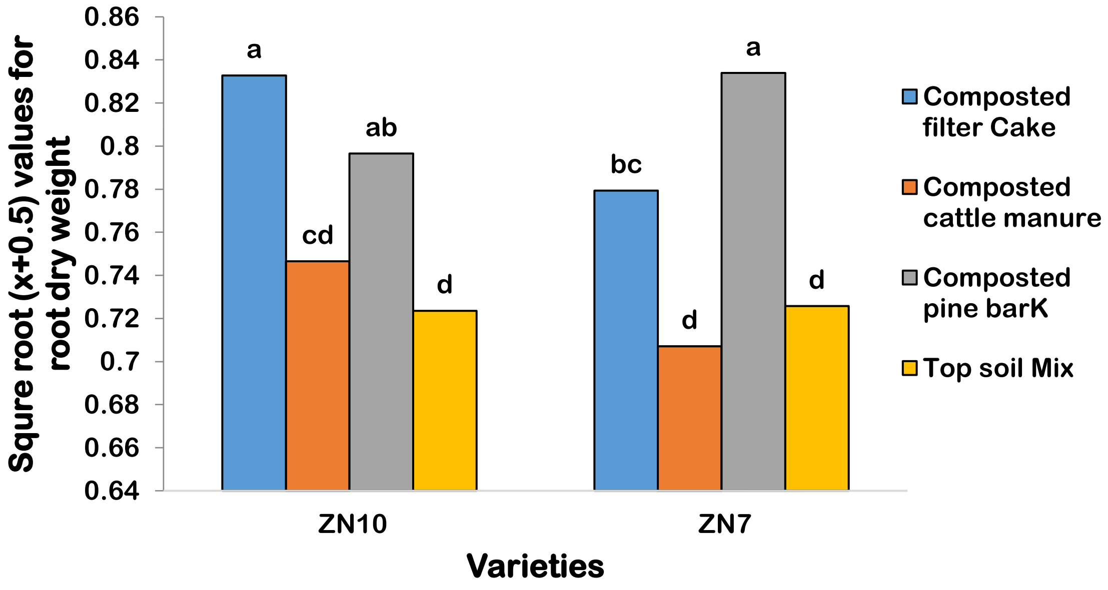

Figure 4.5. Means of square root transformed (x+0.5) values for dry root weight (g) 6 WAP as influenced by interaction of plant media and variety.

4.1.6 Effect of different types of plant media and variety on total biomass accumulation (dry) weight.

Square root total biomass accumulation was significantly affected by the interaction of treatments (Figure 4.64.6; P<0.05; Appendix 6). At variety ZN10, Composted filter cake had the highest mean square root value for total biomass accumulated (1.05) which was statistically different from all other treatment interactions at 6 WAP. At variety ZN10 mean square root value for Composted filter cake was significantly higher and statistically different from all other treatments with Composted cattle manure and Top soil mix not statistically different from each other. Composted filter cake and Composted pine bark were not statistically different at variety ZN7 but showed high significance at variety ZN10. At variety ZN7, Composted cattle manure had the lowest mean square root value which was statistically different from all other treatments which were not significantly different as shown in Figure 4.64.6.

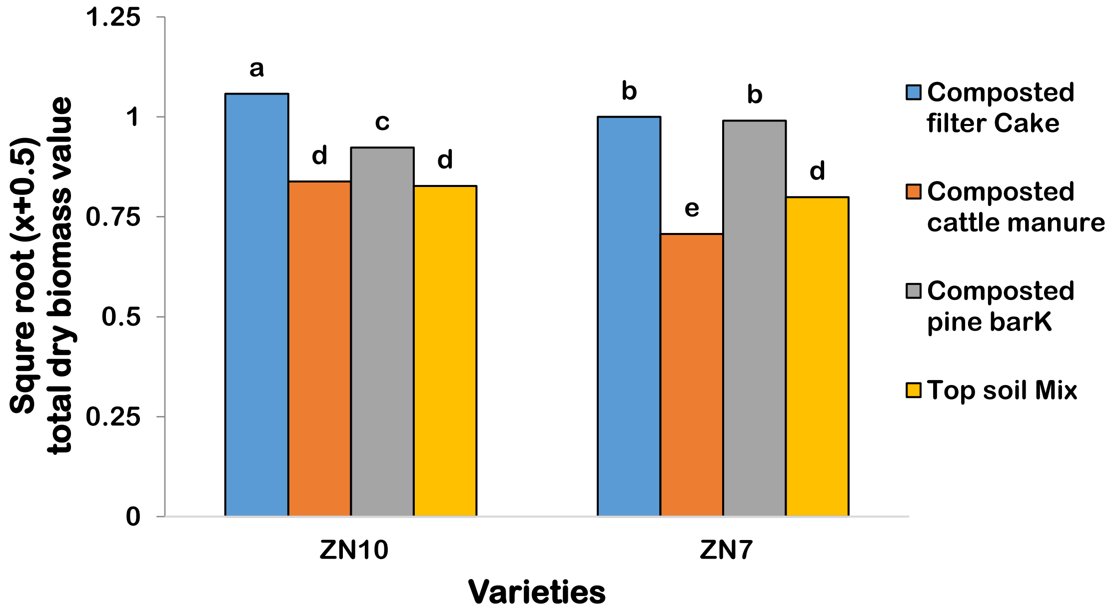

Figure 4.6. Means of square root transformed (x+0.5) values for total biomass accumulation (g) per speedling at 6WAP as influenced by interaction of plant media and variety.

Experiment 2. Effect of intra row spacing using Bud chip technology on growth and yield of sugarcane (*Saccharum officinarum* L) varieties.

4.2.1 Stalk height

4.2.1.1 Effect of intra-row spacing on shoot height (m) at 24 and 26 WAP.

There was no interaction of intra-row spacing and variety on shoot height (P<0.05) at 24 and 26 WAP. Double row planting of three eyed setts, had the highest shoot height which was not statistically different from 0.3 m bud chip speedlings and 0.5 m single eyed speedlings at 24 WAP with 0.9 m bud chip speedlings recording the least shoot height which was statistically the same with that of 0.7 m bud chip speedlings as shown in Figure 4.7. At 26 WAP, Double row planting of three eyed setts, 0.3 m bud chip speedlings, 0.5 m bud chip speedlings, 0.7 m bud chip speedlings and 0.5 m single eyed speedlings were at statistical parity while 0.9 m bud chip speedling only showed statistical difference from Double row planting of three eyed setts as shown in Figure 4.7.

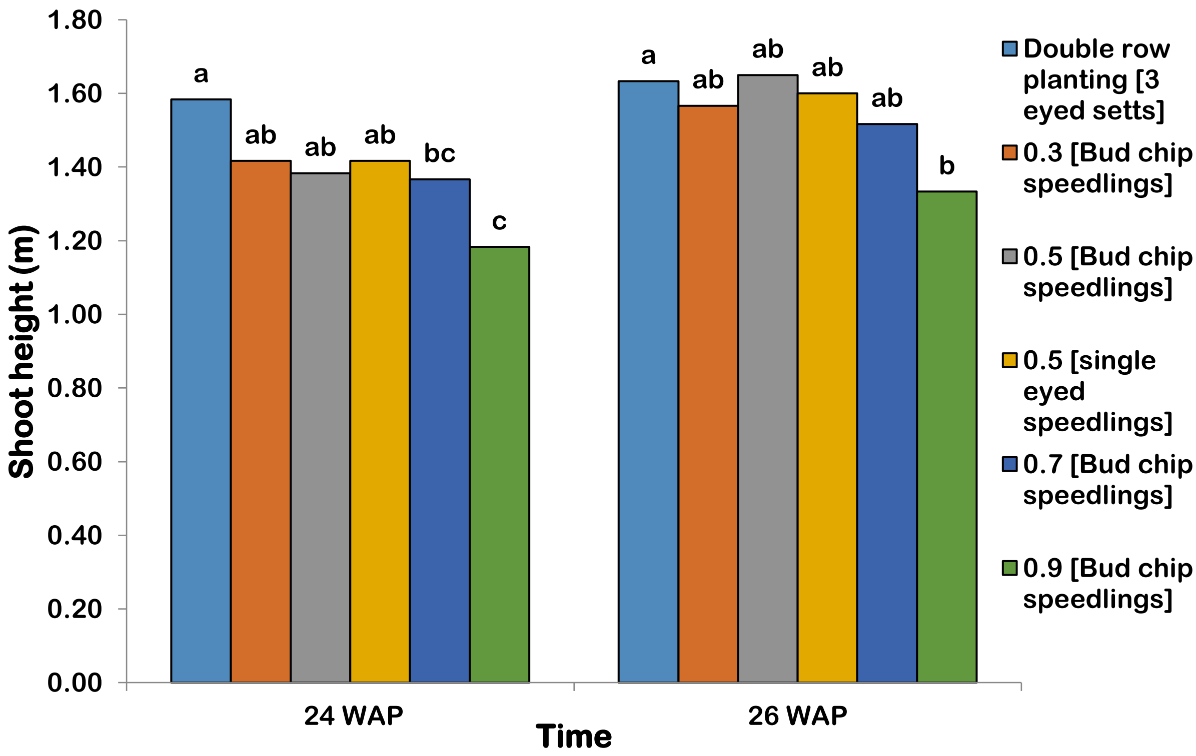

Figure 4.7. Effect of intra-row spacing on shoot height (m) of sugarcane.

4.2.1.2 Effect of variety on shoot height (m) at 9, 14, 17, 19, 24 and 26 WAP.

Shoot height was significantly influenced by variety (P<0.05; Appendices 7-11). ZN7 had the significantly the highest shoot height across the assessment period with the exception at 14 WAP were ZN10 exhibited significantly high shoot height than ZN7 shown in Figure 4.8. ZN7 outweighed ZN10 with a 15 % height difference which was significantly different (P<0.05) at 26 WAP.

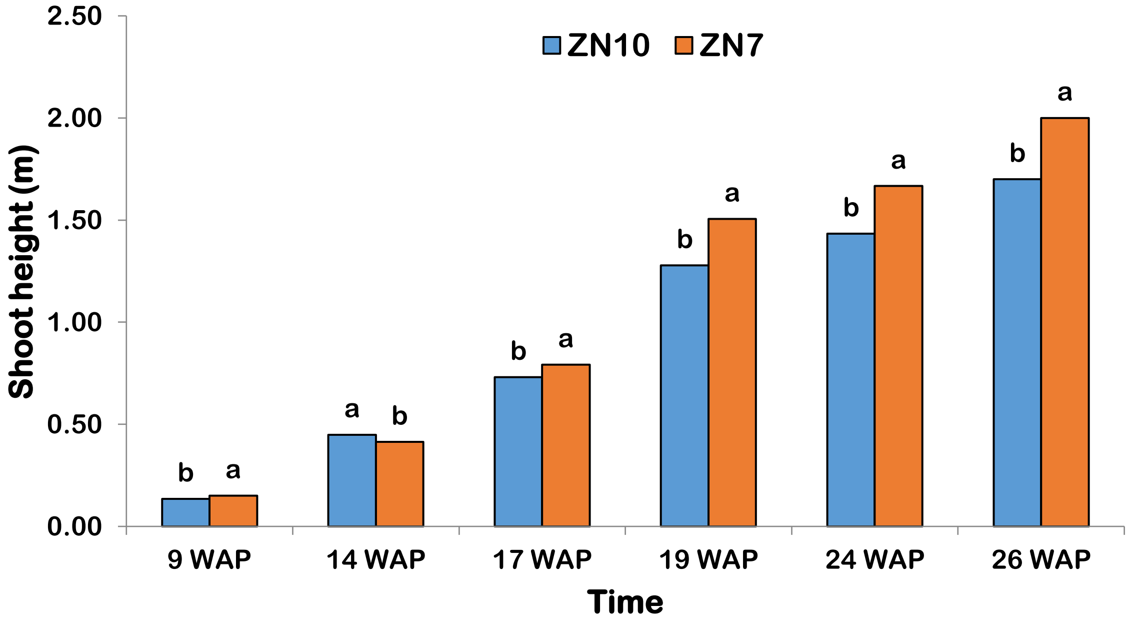

Figure 4.8. Effect of variety (ZN10 and ZN7) on shoot height (m).

4.2.2 Stalk diameter.

Analysis of variance revealed that stalk diameter was only influenced by main effects (intra-row spacing and variety) and not by the interaction of treatments (P<0.05).

4.2.2.1 Effect of intra-row spacing on stalk diameter (cm) at 57 WAP.

Significant differences (P<0.05; Appendix 21) were observed among the different intra-row spacing on stalk diameter (Figure 4.94.9). Single eyed speedlings spaced at 0.5 m, had the highest stalk diameter (57 WAP) although not statistically different from 0.5 m bud chip speedlings, 0.7 m bud chip speedlings and 0.9 m bud chip speedlings. Stalk diameter lessened as intra-row spacing decreased, with conventional double row planting of three eyed setts and 0.3 m bud chip speedlings recording the least stalk diameter (57 WAP) which were not statistically different from each other (Figure 4.9).

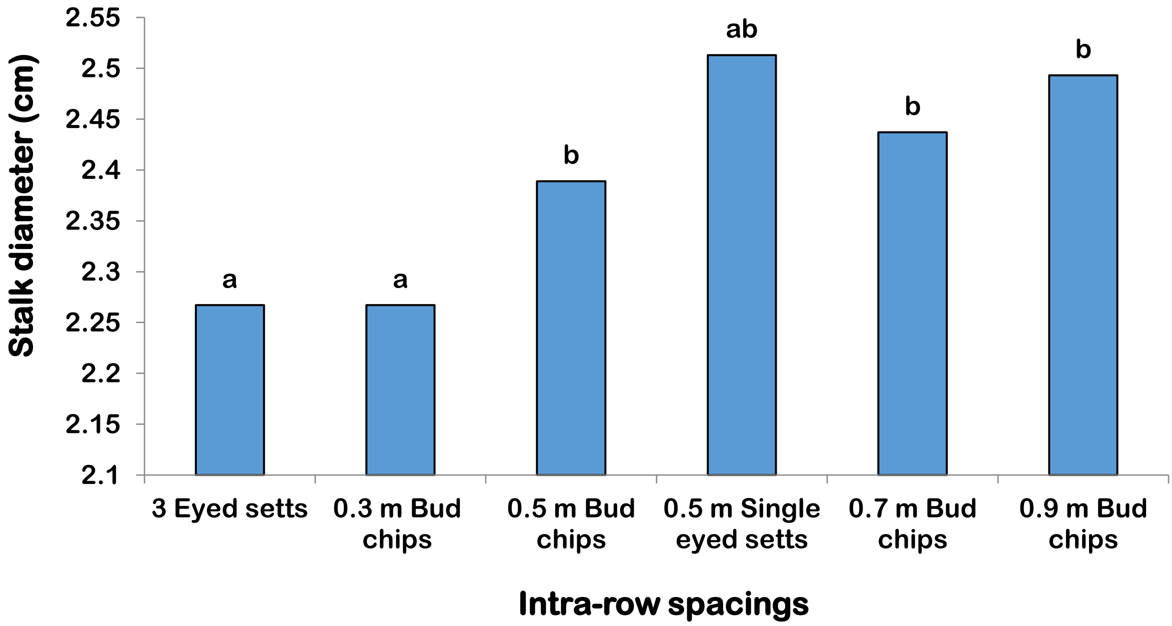

Figure 4.9. Effect of intra-row spacing on stalk diameter (cm) at 57 WAP.

4.2.2.2 Effect of variety on stalk diameter (cm) at 57 WAP.

Statistically there were significant differences ($P<0.05$) among the ZN7 and ZN10 varieties used. ZN7 had the highest stalk diameter while ZN10 gave the least stalk diameter which was statistically different from ZN7 (Figure 4.10).

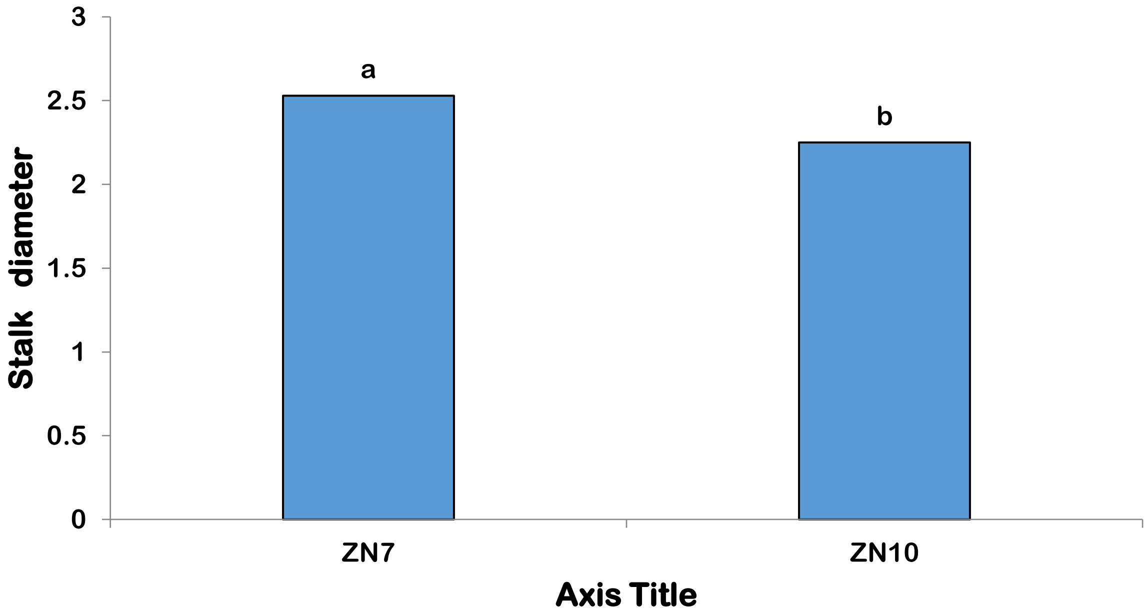

Figure 4.10. Effect of variety on stalk diameter (cm) 57WAP.

4.2.3 Effect of intra-row spacing and variety interaction on tiller population per stool.

There was an interaction between intra-row spacing and variety on number of shoots per stool ($P<0.05$; Appendices 18-19). The number of tillers per stool for the varieties ZN10 and ZN7 increased with increasing intra-row plant spacing. At variety ZN10, 0.7 m bud chip speedlings recorded a higher tiller population per stool than 0.9 bud chip speedlings, which was not significantly different from each other while at variety ZN7, 0.9 m bud chip speedlings recorded a high number of tillers that was significantly the same with 0.7 m bud chip speedling. Intra-row spacing of 0.5 m bud chip speedlings and 0.5 m single eyed speedlings recorded the same number of tillers per stool which were not significantly different under either variety ZN10 or ZN7 as shown in Figure 4.11. Double row spacing of three eyed setts, either for ZN10 or ZN7, gave the least number of tillers per stool which were not significantly different.

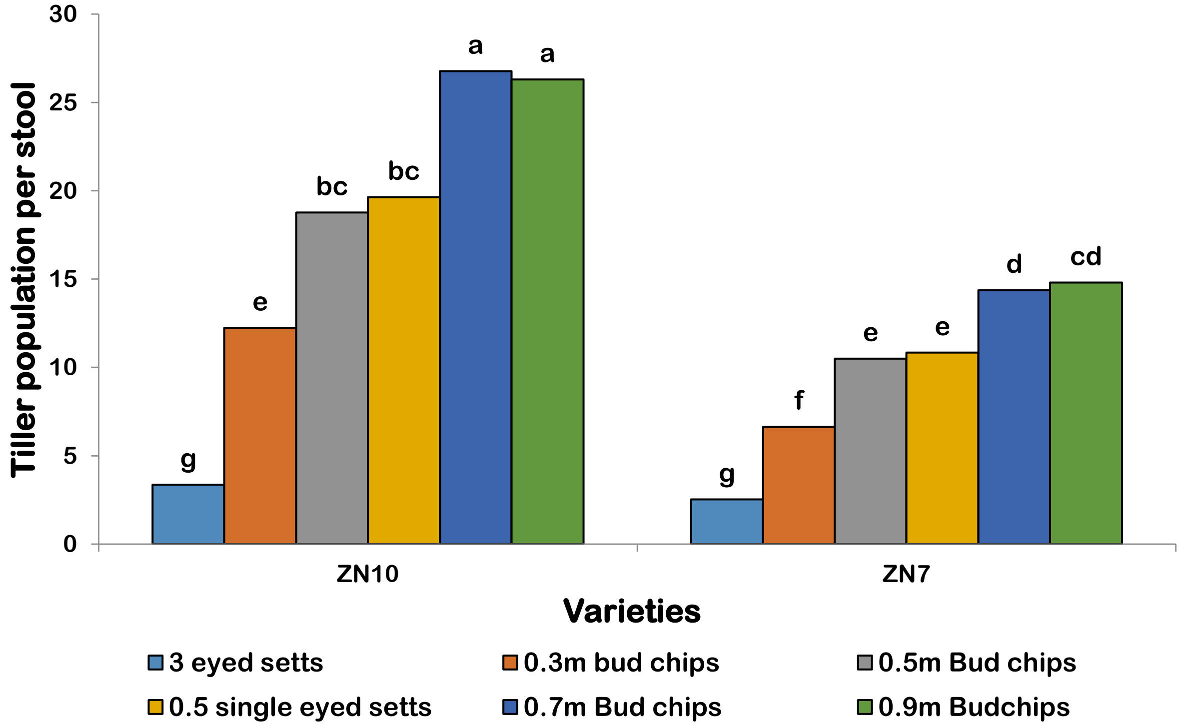

Figure 4.11. Effect of interaction of intra-row spacing and variety on shoot number per stool 26 WAP.

4.2.4 Shoot population

4.2.4.1 Effect of intra-row spacing on shoot population ha^{-1}.

There was no interaction (P<0.05) between intra-row spacing and variety on tiller population per ha. The tillers dynamics across the growing period of sugarcane under different intra-row spacing shows that tiller population increased very sharply between 9 and 14 WAP with a further more reduction observed until optimum plant population was reached. The highest tiller population of (323477 tillers ha^{-1}) was recorded at 17 WAP (grand growth stage) from double row planting of three eyed setts followed by 0.3 m bud chip speedlings, 0.5 m single eyed speedlings, 0.5 m bud chip speedlings and 0.7 m bud chip speedling while the least tiller population was from 0.9 m bud chip speedling (114080 tillers ha^{-1}) as shown in Figure 4.12.

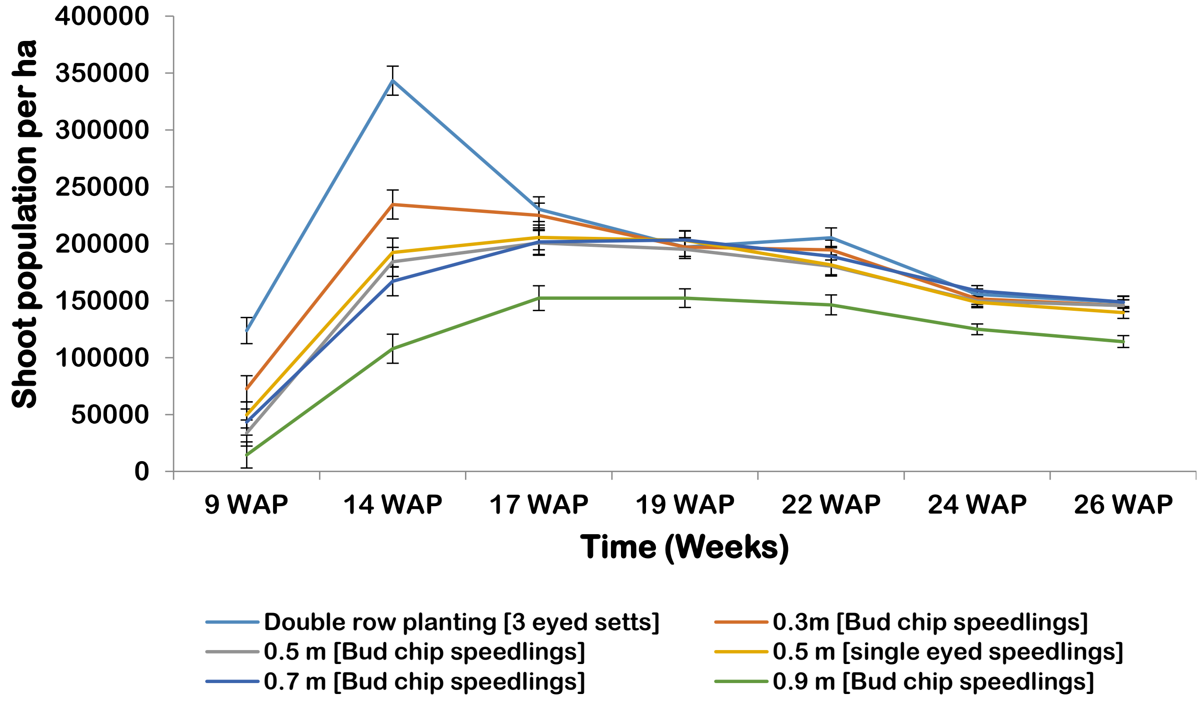

Figure 4.12. Effect of intra-row spacing on shoot population per hectare.

4.2.4.2 Effect of variety on shoot population ha^{-1}

Analysis of variance revealed that shoot population was significantly affected by variety ($P<0.05$). ZN10 and ZN7 were not statistically different at 9 WAP, followed by a sharp rise in shoot population for both varieties, reaching peak population with ZN10 28.62% greater than ZN7 at 14 and 17 WAP respectively as shown in Figure 4.13. The shoot population for ZN10 and ZN7 gradually showed a declining trend respectively from 17–26 WAP and 14 – 26 WAP.

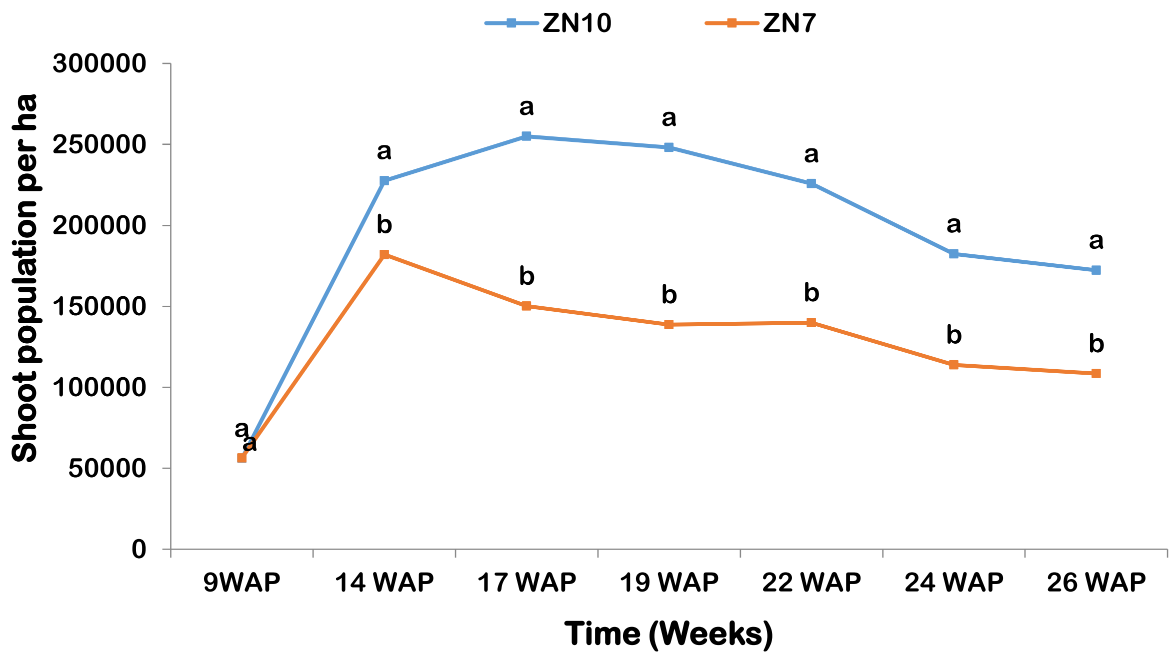

Figure 4.13. Effect of variety on shoot population ha^{-1}.

4.2.5 Leaf nitrogen (N %) content.

4.2.5.1 Effect of intra-row spacing on leaf nitrogen (N %) content

Leaf nitrogen content was significantly influenced by the effect of intra-row spacing (P<0.05; Appendix 20). Leaf nitrogen increased with increase in intra-row spacing respectively with 0.9 m and 0.7 m bud chip speedlings and 0.5 m bud chip speedlings having the highest leaf nitrogen % content which was not statistically different (Figure 4.14). Double row planting of three eyed setts and 0.3 m bud chip speedlings had the least accumulated leaf nitrogen content which was not statistically different from each other and also from 0.5 m bud chip speedlings.

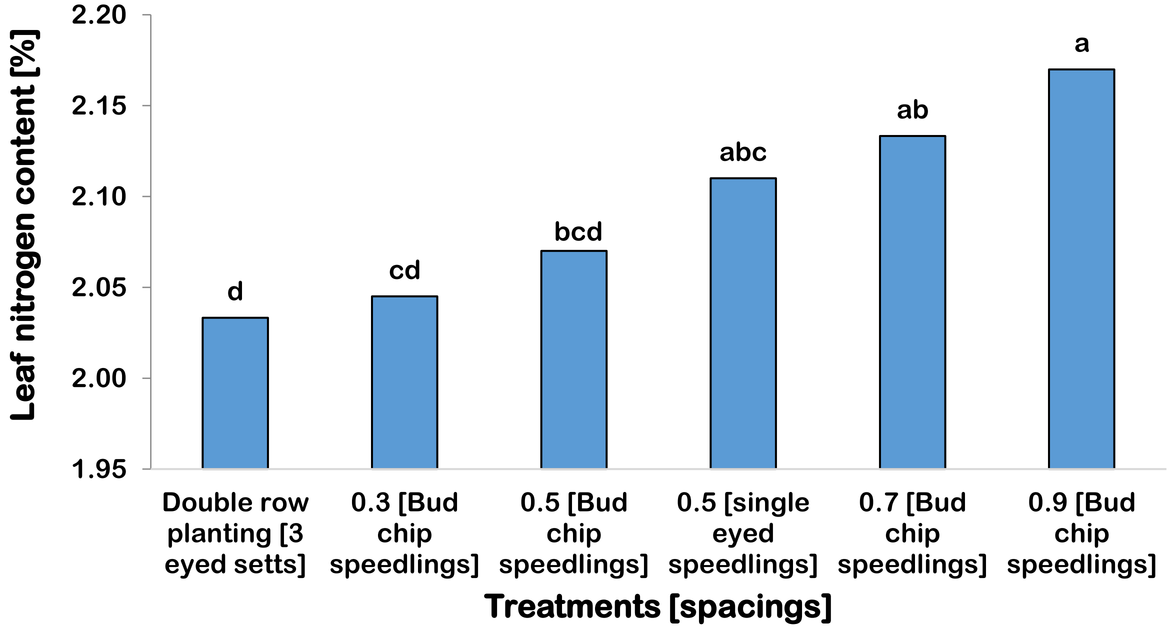

Figure 4.14. Effect of intra-row spacing on leaf nitrogen % content at 22 WAP.

4.2.5.1 Effect of intra-row spacing on leaf nitrogen (N %) content.

The main effect of variety was significant at ($P<0.05$; Appendix 20) with ZN10 having 4.2 % more leaf nitrogen % which was significantly different from ZN7 (Figure 4.15).

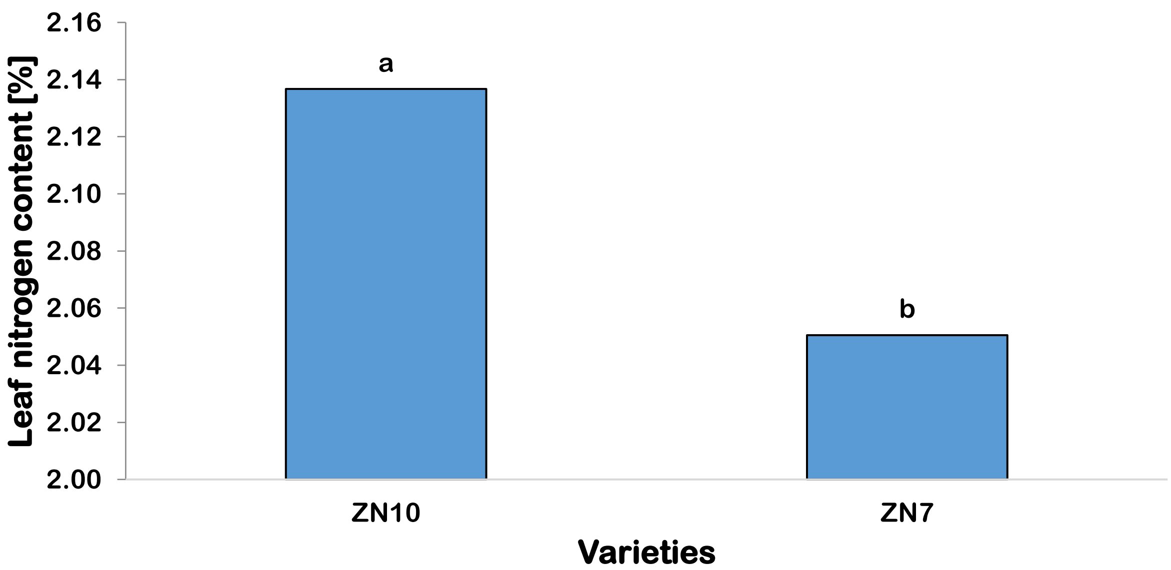

Figure 4.15. Effect of variety on leaf nitrogen % content at 22 WAP.

4.2.6 Effect of intra-row spacing and variety on total number of millable cane ha^{-1} at harvest (57WAP).

The number of millable stalk was affected by the interaction of the main effects of intra-row spacing and variety (P<0.05; Appendix 22). At variety ZN10, 0.7 m bud chip speedlings and 0.5 m bud chip speedlings had almost the same number of millable stalks ha^{-1} which were not statistically different while at variety ZN7 0.5 m bud chip speedling had 10% higher number of millable stalks than 0.7 m bud chip speedlings as shown in Figure 4.16. At variety ZN10, 0.7 m bud chip speedlings was significantly different from 0.9 m bud chip speedlings recording 13% higher number of millable stalks than the later while at ZN7, 0.7 m bud chip speedlings and 0.9 m bud chip speedlings were not statistically different (P<0.05).

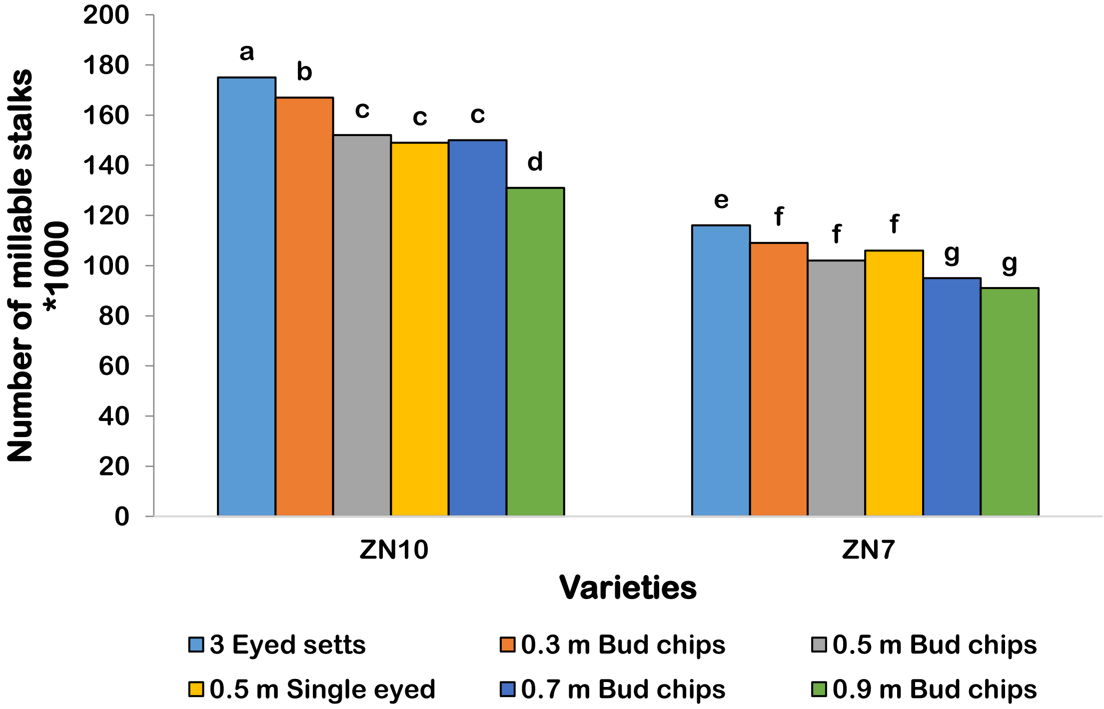

Figure 4.16. Effect of treatment interaction on number of millable stalks ha-1 57 WAP.

4.2.7 Effect of variety on stalk weight (kg) at harvest (57 WAP).

There was an interaction (P<0.05; Appendix 23) between intra-row spacing and varieties stalk weight was significantly affected by the effect of variety and not by intra-row spacing and interaction of variety and intra row spacing. ZN7 had high mean stalk weight which was statistically different from ZN10 (Table 4.1).

Table 4.1 Effect of variety on stalk weight (kg) at harvest (57 WAP).

Treatment	Stalk weight (kg)
ZN7	1.7[a]
ZN10	1.2[b]
P value	0.001
C.V %	18.1

4.2.8 Effect of intra-row spacing and variety on cane yield (tons ha^{-1}) at harvest (57WAP).

There was also no interaction between intra-row spacing and variety on cane yield (P>0.05).

4.2.9 Effect of interaction of intra-row spacing and variety on sugar yield (tons ha^{-1}) at harvest (57WAP).

There was no interaction (P<0.05) between intra-row spacing and variety on sugar yield.

4.2.10 Cost benefit analysis

Cost benefit analysis of different intra-row plant spacing revealed that the highest return per dollar of $163.35 per hectare was received from 0.9 m bud chip speedlings and it doubled that of three eyed setts. Treatment 0.7 m bud chip speedling gave a return per dollar of $137.90 following 0.9 m bud chip speedlings and the conventional planting of three eyed setts had the least return per dollar of $19.49 while 0.5 m single eyed speedlings recorded the highest net benefit ($19 515.77) as shown in Figure 4.17. On Commercial scale, new income realized from the saving in seed material increased with increasing intra-row spacing, with 0.9 m recording the highest net income ($292671.45) while no income was recorded under the conventional planting of three eyed setts. Generally return per dollar and new cost from saved seed material in the whole industry increased with increasing intra-row spacing as shown in Figure 4.17.

	Units price [USD]					
	Three eyed setts	*Bud chip speedlings*	*Bud chip speedlings*	*Single eyed setts*	*Bud chip speedlings*	*Bud chip speedlings*
System costs	-	**0.3 m**	**0.5 m**	**0.5 m**	**0.7 m**	**0.9 m**
Bud Chip Technology inputs						
Plant population per ha	104500	22222	13333	13333	9524	7407
Sugarcane bud chipper (manual) plus disc cutter	$0.00	$0.84	$0.50	$0.50	$0.36	$0.28
Seed material	$700.00	$148.86	$89.31	$89.31	$63.80	$49.62
Plant growth media [4 bags of media per 4200 cells), half milo half pine bark	$0.00	$95.24	$57.14	$57.14	$40.82	$31.75
Cost of trays/ha [24 by 8 cells] at $1500 per 92160 cell]	0	$14.47	$8.68	$8.68	$6.20	$4.82
Labour (planting)	0	0	0	0	0	0
Seed collection and Removal of bud chips/cutting 3 eyed setts	12	$2.55	$1.53	$1.53	$1.09	$0.85
Greenhouse speedling management (0.5 hrs for 50 trays by 192 cells)	$0.00	$52.95	$31.77	$31.77	$22.69	$17.65
New cost	$712.00	$314.91	$188.94	$188.94	$134.96	$104.97
New income	$13,874.00	$13,846.00	$13,234.00	$14,491.00	$13,384.00	$11,808.00
Cost saved	$0.00	$4,554.62	$5,024.77	$5,024.77	$5,226.26	$5,338.21
Gross income	$13,874.00	$18,400.62	$18,258.77	$19,515.77	$18,610.26	$17,146.21
Net benefit	$13,162.00	$18,085.71	$18,069.83	$19,326.83	$18,475.30	$17,041.24
Return per dollar	$19.49	$58.43	$96.64	$103.29	$137.90	$163.35
Assumptions						
1. Seedcane cost is @ $350 per 5-ton stack.						
Bud cheaper cost/ha; $1450.00 5 yr depreciation, 32000 buds per day						
2. Price of tray@ $3 per tray.						
3. One shift @ $6 per day per worker.						
4. Three persons can produce minimum of 32 000buds						
5. Pine bark cost @ $9 per 6-8mm 50kg bag [Volumetric]						
6. The cost of planting labour is the same in both systems.						
10 % plough-out, 450 ha required convectional,	0.000	0.787	0.872	0.872	0.909	0.929
Total hectarage across the industry: 45 000 ha	0	354.306	392.584	392.584	408.988	418.102
New income generated from seed saving in the industry annually	0	248014.35	274808.61	274808.61	286291.87	292671.45

Figure 4.17. Cost benefits analysis for different intra-row spacing used in bud chip technology.

CHAPTER FIVE

DISCUSSION

5.1 Expt. 1. Effect of plant media (substrate) and varieties on emergence and growth of speedlings raised from sugarcane bud chips.

5.1.1 Effect of different plant medium and variety on bud emergence %.

Composted pine bark recorded the highest emergence % followed by filter cake and this may be ascribed to high porosity, low bulk density, aeration, water holding capacity as well as the presence of humic-like materials and other plant growth promoters;that might have been produced by micro-organisms during composting (Arancon, et al, 2004; Anon, 2015). However, the present results of poor germination in Composted cattle manure and Top Soil Mix may. There was an indication of burning of buds by Composted cattle manure which may be ascribed to high thermal conductivity of cattle manure (Eden, et al; 2012). Generally soil potting media have a tendency of developing a crust on the surface resulting in poor emergence owing to failure of the bud to break the crusting due to reduce oxygen diffusion, and moisture infiltration.

On the other hand, Composted manure and top soil mixes are difficult to standardize (Kessler, 2004), because they might contain residual herbicides which might affect seed germination and growth of plants. In addition, Hasanuzzaman, (2015), asserts that manure from cattle fed on Johnson grass (Sorghum halepense) had an inhibitory effect on root and shoot growth of sugarcane due to exhibited true and functional allelopathy of Johnson grass shoot and root parts. The present results in the variation of bud emergence % for the ZN10 and ZN7 varieties is in agreement with ascertainment by VanDellewijn, (1952), who stated that varieties differ in their initial rate of germination because some varieties develop their roots prior to shoots and in others vice vesa. Research carried out at ZSAES by (Zhou, 2003)revealed that variety ZN7 had the lowest emergence %. This suggest that emergence rate is function of Gene*Environment interaction.

5.1.2 Effect of plant medium and variety on shoot height per speedling (mm).

Composted filter cake and Composted pine bark at variety ZN10 and ZN7 resulted in highest shoot height because of high initial nutrient constituent accompanied with moderate porosity and water holding capacity which promoted vigorous shoot growth (Masaka, 2007; Roth, 1971). Prado, et al; (2013) documented that filter cake can be an a good plant media for the production of seedlings as its use resulted in taller plants with more leaves area, larger dry matter owing to high P uptake followed by plant root and shoot growth (Utami, et al; 2012). At ZN10 Top soil mix was higher than Composted pine bark but not significantly different, while at ZN7 Composted pine bark was significantly higher than Top soil mix. This can be attributed to the ability of ZN10 to mine nutrients in Top soil mix and on the other hand ZN10 is a fast grower while ZN7 was limited by the crusting of the Top soil mix while pine bark supported its easy in shoot growth. Varietal differences in regards to physiology of plant growth have been documented and these can be some of the major causes for this variation as according to VanDellewijn, (1952) and Zhou, (2003).

5.1.3 Effect of different types of plant medium and variety on dry shoot weight per speedling.

Composted filter cake recorded the highest shoot dry weight value which was highly significant from all treatment combinations and this is due to high electrical conductivity in Composted filter cake than in Composted pine bark as well as the capacity of Composted filter cake to provide nutrition and moisture that promoted vigorous plant growth. Yungcong and Graetz, (1996) reported high seedlig height, shoot weight and lower root weight in speedlings grown in filter cake since it contains appreciable amounts of N, P, Ca, K and Mg (Roth, 1971). At variety ZN10, mean values for Composted cattle manure and Top soil mix were not significantly different while at variety ZN7, Composted cattle manure and Top soil mix were significantly different with Composted manure recording the least mean square root shoot dry weight value owing to high thermal conductivity which promotes high evapotranspiration resulting in moisture stress. This triggers the production of abscisic acid. Abscisic acid is one of the growth hormones that is released by plant roots and its translocated to the leaves were it causes leaf rolling, increases stomatal conductance and also accelerates leaf senescence resulting in stunted plant growth (Zhang et al, 2011; Zaidi, 2002). In addition, high shoot dry weight in ZN10 compared to ZN7exhibit that the variety has got high influence on shoot development rate as and this characteristic is genetic.

5.1.4 Effect of different types of plant medium and variety on dry root weights.

The result show that at variety ZN10, Composted filter cake had a high root dry weight than Composted pine bark while at ZN7 it Composted pine bark recorded the highest root dry weight than Composted filter cake. This might suggest that ZN7 develops its roots first and when a plant is under abiotic/nutrient stress, it undergoes physiological modifications to suit the prevalent conditions and one of these is root growth under nitrogen and phosphorus deficient conditions owing to leaching during irrigation. Findings by Zhang, et al; (2011), stated that, phosphorous deficiency in media cultures induced more root hair formation, in a bid to search for new sources of nutrient rich zones. Further studies by Sarma and Gogoi, (2015) revealed the literature on shoot: root relationship elucidating that, when soil nutrients are limiting. The requirements of the roots are met first at the expense of the shoots and when photosynthesis is limiting, the requirements of the shoots are met first at the expense of the roots. Thus the plant channels it`s assimilates towards the development of the root structures on the expense of shoots, while in-search of water and nutrition.Consequently high root density in Composted pine bark can be attributed to low nutrient value of the plant media as well as its friability which allows aeration and root respiration and penetration. Top soil mix and Composted cattle manure had the least dry root weights and this might be ascribed to high compaction and presence of allelochemicals in Composted cattle manure respectively. The formation of a hard crust in top soil mix also is another contributing factor to poor shoot and root development due to insufficient supply of moisture and oxygen required by the plant for root respiration.

5.1.5 Effect of different types of Plant media and variety on total dry weight of biomass accumulated.

At ZN10 and ZN7, Composted filter cake recorded the highest total biomass is supported by higher content of available nutrients (especially N and P_2O_5) as well as better rate of mineralization of Composted filter cake (Sarma et al, 2015). Current results of ZN7 in Composted filter cake and Composted pine bark, show that ZN7 has high biomass compensation capacity in terms of shoot and root dry weights which is respectively high and low in Composted filter cake and low and high in Composted pine bark and this might be attributed to genetic influence of ZN7 as it had high root density as it tends to develop the roots first on the expense of the shoot as described by VanDellewijn, (1952).

5.2 Expt. 2. Effect of intra row spacing using Bud chip technology on growth and yield of sugarcane (*Saccharum officinarum* L) varieties.

5.0 Discussion

5.1.1 Effect of intra-row spacing and variety on shoot height using Bud chip technology.

The results from this study show that, double row planting of three eyed setts and 0.9 bud chip had the highest shoot height 24 and 26 WAP which is an indication of intra-plant to plant competition for space and light which triggers lateral plant growth on the expense of stalk diameter. These results are at par with findings by Abuzar, et al, (2011) and Sangoi, (2001) who confirmed that the use of high plant populations increased inter plant competition for light, water and nutrients which was detrimental to plant growth as it increased apical dominance thus resulting in increased stalk height reaching up to 2-3 m (Bull, 2000; Mahmoud, et al, 2013). The main stalk will be acting as a stronger sink for photoassimilates on the expense of secondary and tertiary tillers as confirmed by high tiller mortality in the double row planting system of 3 eyed setts as compared to spaced transplants. At 26 WAP, 0.9 m bud chip speedlings gave the least shoot height which was not significantly different from all other intra-row plant spacing with the exception double row planting of setts. Raskar, et al, (2003) revealed that shoot height, millable canes and number of internodes did not differ significantly by intra-row spacing but cane girth and per cane weight increased significantly at wider intra-row spacing of 90 cm. This might be due to reduced levels of apical dominance of the main stalk due to the presence of more space which promote development of secondary and tertiary tillers which act as the main sinks of photoassimilates on the expense of apical growth of the primary shoot.

5.1.2 Effect of intra-row spacing and variety on stalk diameter using Bud chip technology.

Single eyed speedlings spaced at 0.5 m, recorded the highest stalk diameter although not statistically different from 0.5 m bud chip speedlings, 0.7 m bud chip speedlings and 0.9 m bud chip speedlings. Stalk diameter increases as intra-row space increases owing to reduced intra-plant competition for space which causes increase in plant height on the expense of plant diameter. Research work by Raskar et al, (2003) at Rahuri reported that in plant cane spaced at 0.9 m intra-row spacing recorded the highest stalk diameter as compared to 0.3 and 0.6 m intra-row spacing and these results are at parity with the findings by Rahman, (2012) and Mahmoud, et al; (2013), revealed that doubling plant density significantly increased stalk diameter by 10.67 % in the plant crop. Such effect might have been due to inter plant competition for light and mineral nutrients (Abo El-Wafa, et al, 2001; Mahmoud, et al, 1999 and Mokadem, 1994).

5.1.3 Effect of intra-row spacing and variety on number of tillers per stool and tiller population ha^{-1} using Bud chip technology.

Number of shoots per stool varied significantly due to interaction of intra-row spacing and variety. At variety ZN10, 0.7 m bud chip speedlings recorded a higher tiller population per stool than 0.9 bud chip speedlings, which was not significantly different from each other while at variety ZN7, 0.9 m bud chip speedlings recorded a high number of tillers that was significantly the same with 0.7 m bud chip speedling. The interaction can be attributed to the elastic limits of varieties in tiller production in which as intra-row spacing increased, more tillers per clamp were produced and as intra-row spacing decreased, tiller production was compromised due to intra-plant competition (Netsanet, et al, 2014)(Zhou, 2003) leading to a decline in tiller population per plant. These results are at parity with findings by Budi, (2016); Rahman, (2012) and Imam, et al, (1988) who alluded that tiller population per clamp $stool^{-1}$ were higher at low density planting and lower at dense intra-row plant spacing of 0.45 and 1.20 m respectively having a limit were any further increase in spacing will realize no gain in tiller population per plant.

In the double row planting of three eyed setts, the initial high tiller population reaching a maximum 17 WAP (Fig 8) can be attributed to high plant density which produced secondary tillers in the grand growth stage. On the other hand, the detrimental effect of high tiller mortality in the conventional double row planting of three eyed setts might be due to low light co-efficient extinction owing to fast canopy development which shades the developing secondary tillers and competition for nutrition and moisture (Ibeawuchi, et al, 2008). These results are at par with research work by Vasantha, et al, (2014) and Imam, et al, (1988), revealed, that tiller mortality (60-120 DAP) increased with plant density because tillering and tiller senescence are sensitive to light competition and are driven by the state of the existing canopy. Treatment 0.7 and 0.9 m bud chip speedlings intra-row spacing showed high tertiary tiller development owing to high shoot multiplication ratio worked out to be 1:40 against 1:10 for conventional use of three eyed setts (Budi, 2016). The difference among varieties in the parameters considered indicates the presence of genotypic variation (Netsanet, et al, 2014; Tsehay, 1993; Worku, 2001; Zhou, 2003), between ZN10 a high population and ZN7 a low population varieties.

5.1.4 Effect of intra-row spacing and variety on leaf nitrogen content % using Bud chip technology.

Leaf nitrogen increased with increase in intra-row spacing respectively with 0.9 m and 0.7 m bud chip speedlings having the highest leaf nitrogen % content which was not statistically different. This can be attributed to the presence of newly formed secondary and tertiary tillers which will be acting a strong sinks for photoassimilates and luxurious nitrogen utilization due to reduced plant-plant competition. Double row planting of three eyed setts and 0.3 m bud chip speedlings had the least accumulated leaf nitrogen content which was not statistically different from each other and also from 0.5 m bud chip speedlings. Low leaf nitrogen content in conventional planting of three eyed setts might be ascribed to presence of mature leaf chlorophyll molecules (Bokhtiar et al, 2007) and less available nitrogen as it had been utilized by the dead tillers. The statistical difference in leaf nitrogen per variety can be due to the genetic efficiency (Zhou, 2003) of different varieties to uptake and utilize available nitrogen in the soil.

5.1.5 Effect of intra-row spacing and variety on stalk weight using Bud chip technology.

Mean stalk weight was significantly affected by variety but not by intra-row spacing and the interaction. Highest mean stalk weight was recorded in ZN7 and it was significantly different from ZN10. Similarly, Muhammad et al; (2002) found significant differences among different sugarcane genotypes in mean stalk weight per stalk, thus suggesting that the growth of the stalk is varietal and limitedly influenced by spacing. Basically, cane weight is a function of stalk diameter, stalk height and density (Orgeron, 2003; Nosheen and Ashraf, 2003), thus the decrease in stalk weight might be attributed to a decrease in cane thickness and stalk height spacing (Ayele and Tegene, 2014) which produces thinner stalks.

5.1.6 Effect of intra-row spacing and variety on total number of millable cane ha^{-1} using Bud chip technology.

At variety ZN10, 0.7 m bud chip speedlings and 0.5 m bud chip speedlings had almost the same number of millable stalks ha^{-1} which were not statistically different while at variety ZN7, 0.5 m bud chip speedling had 10% higher number of millable stalks than 0.7 m bud chip speedlings. This owes to a lower compensatory ability and tiller maintenance of ZN7 with increasing plant spacing. Generally, number of millable stalks increased with decreasing intra-row spacing at both varieties. Similar to this result, Feyissa, et al; (2008) also observed variation on number of millable cane stalks between varieties as well as intra-row spacing. This is in agreement with the findings by Nestanet et al, (2014), who asserts that high density planting rates resulted in higher number of millable canes than low density planting. Preecha, (2006) also reported that the number of millable canes per unit area were influenced by intra-row spacing of setts.

Wiedenfeld, (2003) concluded that when reduced planting rates were used in commercial sugarcane fields, no reduction in final shoot count was realized compared to the growers` standard planting rates, thus using substantially high seed rate is not necessary to attainment of maximum crop stand.

5.1.7 Effect of intra-row spacing and variety on cane yield ha^{-1} using Bud chip technology.

Cane yield was not significantly affected by the effect either of intra-row spacing or variety. Thse results are at parity with those of Bell et al; (2005) who cocluded that different plant configurations did not produce any differences in cane yield. This was attributed to the ability of sugarcane to compansate for different plant configurations and planting densities through variation in stalk number and individual stalk weight Tsehay, (1993); Worku, (2001) and Netsanet, et al, (2014). This means that low density planting compensate for the low stalk population owing to the presence of abundant space, sufficient PAR which promoted high photoassimilates production and partitioning of dry matter during heavy tillering in wider spaced planting, thereby avoiding diversion of complex carbohydrate away from the stalks. On the other hand, varietal differences with regard to cane yield were noted as evidenced by different growth patterns in response to different inter and intra-row plant spacing.

5.1.8 Effect of intra-row spacing using Bud chip technology on sugar yield ha^{-1}.

Statistically, there were no significant differences among the different treatment combination and these results are at parity with findings by Mahmoud, et al, (2013), Sundara, (2003), Netsanet, et al, (2014) and(Tsehay, 1993), who revealed that sucrose percent cane was affected only by the main effect of variety and not by intra-row sett spacing because sugarcane differences in yield could be compensated by higher yield of stalks, cane thickness and consequently the final syrup.

5.1.9 Effect of intra-row spacing using Bud chip technology on cost benefit.

The highest net benefit realized at 0.5 m single eyed speedlings can be attributed to saving in the cost of seed materials accompanied with high yields realised on this treatment as intra-row spacing increased. On the other hand, the ability of sugarcane to compensate on yield parameters resulted in more return per dollar invested being realised even at low seeding rates. These results are at parity with those of and Rahman, et al, (2012), Rahman, et al, (1994) who indicated that the comparative performance of transplanted sugarcane compared to conventional under growers' conditions were estimated that the highest gross return (USD 932.44 ha^{-1}) and gross margin (USD 668.19 ha^{-1}) were obtained respectively.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

5.1 Expt. 1. Effect of plant media (substrate) and variety on emergence and growth of speedlings raised from sugarcane bud chips.

Composted pine bark and Composted manure respectively gave the highest and least bud emergence % which was highly significant ($P<0.05$). At varieties ZN10 and ZN7, Composted filter cake and Composted pine bark was superior to Top soil mix and Composted cattle manure, with Composted cattle manure recording the least shoot height. Varieties ZN10 and ZN7 in Composted filter cake recorded the highest total biomass accumulated while at varieties ZN10 and ZN7, Composted cattle manure recorded the least total biomass accumulated. At varieties ZN10 and ZN7, Composted filter cake and Composted pine bark recorded the highest root dry weight with Composted cattle manure recording the least values. ZN10 is a fast grower than ZN7 in terms of shoot height and shoot dry biomass accumulation.

Recommendations

Composted filter cake is recommended as the most suitable and less costly plant growth medium to use when raising sugarcane bud chips as it is readily available in large quantities at the mills and can support bud growth. Varieties ZN10 and ZN7 can be used when propagating sugarcane using sugarcane bud chips. Furthermore mixing of pine bark and filter cake in ratios need to be considered in order to improve on bud emergence as well as plant growth promoters need also to be taken into cognizance in the attempt to boost the speedling vigor/initial growth.

6.2 Expt. 2. Effect of intra row spacing using Bud chip technology on growth and yield of sugarcane (Saccharum officinarum L) varieties.

For improvement and sustenance of sugarcane productivity, agronomic practices like use of bud chip speedlings should be practiced. From the results of the present study, the following conclusions can drawn, that is All intra-row spacings were comparably the same with regards to plant height with the exception of 0.9 m which recorded the least plant height (26WAP). Double row planting of setts recorded the highest peak which was significantly different from all other treatments (14 WAP) followed by normalization to optimum shoot population for all treatments with the exception of 0.9 m bud chip speedlings which failed to reach the normal plant population. The results indicate that 0.7 m bud chip speedling and 0.9 m bud chip speedling was superior to any other treatments with respect to tiller population per stool, leaf nitrogen content % and cash income (return per dollar and new income generated from saving in seed) and the values reduced with decreasing intra-row spacing. Significantly highest number of millable stalks per ha was recorded in conventional planting of three eyed setts and reduced progressively with an increase in intra-row spacing. Sugarcane had the capacity to compensate on cane and sugar yield under various intra-row spacing and varieties, thereby comparable yield values ($P<0.05$).

Recommendations

Sugarcane farmers are recommended to use a respectively an intra-row spacing of 0.9 m when using bud chips speedlings so as to attain more revenue from high cane yield ha^{-1}, sugar yieldha^{-1} and income realised from saving in seed material. Varieties ZN7 and ZN10 can be used when propagating sugarcane from bud chip speedlings as they compensate under different intra-row spacings to give the same final cane and sugar yield. Further investigations are required to determine the bud chip speedling growth at 1st ratoon so that plant cane and ratoon results can be compared to determine feasibility.

Innovation on mechanical planting of speedlings should be done to establish the feasibility on labour reduction during planting.

APPENDICES

A1: ANOVA for the effect of plant media and variety on emergence % of sugarcane bud chips at 23 DAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	858.81250	429.40625	2.25	0.1417
Variety	1	1976.53500	1976.53500	10.37	0.0062
Growth media	3	23383.26833	7794.42278	40.91	<.0001
Variety*Growth media	3	678.03500	226.01167	1.19	0.3506
Error	14	2667.57417	190.54101		
Total	23	29564.22500			

A3: ANOVA for the effect of plant media and variety on shoot height of sugarcane speedlings at 6 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	212.26083	106.13042	1.02	0.3869
Variety	1	1480.51042	1480.51042	14.19	0.0021
Growth media	3	25553.04792	8517.68264	81.63	<.0001
Variety*Growth media	3	1788.69125	596.23042	5.71	0.0091
Error	14	1460.79917	104.34280		
Corrected Total	23	30495.30958			

A4: ANOVA for the effect of plant media and variety on shoot dry weight of sugarcane speedlings at 6 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	0.00689175	0.00344588	6.51	0.0100
Variety	1	0.00952017	0.00952017	17.99	0.0008
Growth media	3	0.39179783	0.13059928	246.83	<.0001
Variety*Growth media	3	0.03454317	0.01151439	21.76	<.0001
Error	14	0.00740758	0.00052911		
Corrected Total	23	0.45016050			

A5: ANOVA for the effect of plant media and variety on root dry weight of sugarcane speedlings at 6 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	0.00409075	0.00204537	1.14	0.3470
Variety	1	0.00224267	0.00224267	1.25	0.2819
Growth media	3	0.10460017	0.03486672	19.48	<.0001
Variety*Growth media	3	0.01901233	0.00633744	3.54	0.0427
Error	14	0.02506258	0.00179018		
Corrected Total	23	0.15500850			

A6: ANOVA for the effect of plant media and variety on total biomass accumulation of sugarcane speedlings at 6 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	0.02137975	0.01068988	3.05	0.0794
Variety	1	0.02100417	0.02100417	6.00	0.0281
Growth media	3	0.83918767	0.27972922	79.87	<.0001
Variety*Growth media	3	0.08976483	0.02992161	8.54	0.0018
Error	14	0.04902958	0.00350211		
Corrected Total	23	1.02036600			

A7: ANOVA for the effect of plant media and variety on shoot heights 9 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	6.26347222	3.13173611	0.64	0.5373
Variety	1	22.32562500	22.32562500	4.56	0.0442
Spacing	5	64.85534722	12.97106944	2.65	0.0509
Variety*Spacing	5	47.34479167	9.46895833	1.93	0.1296
Error	22	107.8048611	4.9002210		
Total	35	248.5940972			

A8: ANOVA for the effect of plant media and variety on shoot heights 14 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	330.6938889	165.3469444	7.05	0.0043
Variety	1	115.5625000	115.5625000	4.92	0.0371
Spacing	5	365.5380556	73.1076111	3.12	0.0283
Variety*Spacing	5	400.0891667	80.0178333	3.41	0.0197
Error	22	516.219444	23.464520		
Total	35	1728.103056			

A9: ANOVA for the effect of plant media and variety on shoot heights 17 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	728.861667	364.430833	6.78	0.0051
Variety	1	336.722500	336.722500	6.27	0.0202
Spacing	5	2232.565833	446.513167	8.31	0.0002
Variety*Spacing	5	484.739167	96.947833	1.80	0.1536
Error	22	1182.098333	53.731742		
Total	35	4964.987500			

A10: ANOVA for the effect of plant media and variety on shoot heights 19 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	0.10166667	0.05083333	1.91	0.1716
Variety	1	0.46694444	0.46694444	17.56	0.0004
Spacing	5	0.49250000	0.09850000	3.70	0.0139
Variety*Spacing	5	0.06138889	0.01227778	0.46	0.8004
Error	22	0.58500000	0.02659091		
Total	35	1.70750000			

A11: ANOVA for the effect of plant media and variety on shoot heights 24 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	0.20166667	0.10083333	2.93	0.0747
Variety	1	0.49000000	0.49000000	14.22	0.0011
Spacing	5	0.40666667	0.08133333	2.36	0.0738
Variety*Spacing	5	0.21333333	0.04266667	1.24	0.3253
Error	22	0.75833333	0.03446970		
Total	35	2.07000000			

A11: ANOVA for the effect of plant media and variety on shoot heights 26 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.11224	0.05612	1.20	
Spacing	5	0.37197	0.07439	1.59	0.205
Variety	1	0.76781	0.76781	16.37	<.001
Spacing.Variety	5	0.07599	0.01520	0.32	0.893
Residual	22	1.03201	0.04691		
Total	35	2.36002			

A12: ANOVA for the effect of plant media and variety on shoot population 9 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	802000304	401000152	0.76	0.4788
Variety	1	1234728	1234728	0.00	0.9618
Spacing	5	43707111921	8741422384	16.61	<.0001
Variety*Spacing	5	4831345777	966269155	1.84	0.1473
Error	22	11581133834	526415174		
Total	35	60922826565			

A13: ANOVA for the effect of plant media and variety on shoot population 14 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	418988973.68	209494486.84	0.32	0.7282
Variety	1	18761739702	18761739702	28.82	<.0001
Spacing	5	188886316057	37777263211	58.02	<.0001
Variety*Spacing	5	6593459695.7	1318691939.1	2.03	0.1145
Error	22	14323469695	651066804.33		
Total	35	228983974123			

A14: ANOVA for the effect of plant media and variety on shoot population 17 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	1215211766	607605883	1.29	0.2956
Variety	1	98885185938	98885185938	209.76	<.0001
Spacing	5	22898450972	4579690194	9.71	<.0001
Variety*Spacing	5	5371319861	1074263972	2.28	0.0820
Error	22	10371138486	471415385.72		
Total	35	138741307023			

A15: ANOVA for the effect of plant media and variety on shoot population 19 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	132.72222	66.36111	1.23	0.3129
Variety	1	21854.69444	21854.69444	403.60	<.0001
Spacing	5	2631.13889	526.22778	9.72	<.0001
Variety*Spacing	5	295.13889	59.02778	1.09	0.3935
Error	22	1191.27778	54.14899		
Total	35	26104.97222			

A16: ANOVA for the effect of plant media and variety on shoot population 24 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	100.16667	50.08333	0.81	0.4572
Variety	1	13417.36111	13417.36111	217.29	<.0001
Spacing	5	2446.91667	489.38333	7.93	0.0002
Variety*Spacing	5	201.80556	40.36111	0.65	0.6619
Error	22	1358.50000	61.75000		
Total	35	17524.75000			

A17: ANOVA for the effect of plant media and variety on shoot population 26 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	1.885E+08	9.425E+07	0.87	
Spacing	5	5.309E+09	1.062E+09	9.83	<.001
Variety	1	3.681E+10	3.681E+10	340.79	<.001
Spacing.Variety	5	5.592E+08	1.118E+08	1.04	0.422
Residual	22	2.376E+09	1.080E+08		
Total	35	4.524E+10			

A18: ANOVA for the effect of plant media and variety on shoots per stool in 19 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	2.187222	1.093611	0.80	0.4622
Variety	1	561.690000	561.690000	410.64	<.0001
Spacing	5	1385.015556	277.003111	202.51	<.0001
Variety*Spacing	5	134.073333	26.814667	19.60	<.0001
Error	22	30.092778	1.367854		
Total	35	2113.058889			

A19: ANOVA for the effect of plant media and variety on shoots per stool 26 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.5675	0.2837	0.40	
Spacing	5	766.2691	153.2538	217.78	<.001
Variety	1	220.8770	220.8770	313.88	<.001
Spacing*Variety	5	91.3859	18.2772	25.97	<.001
Residual	22	15.4814	0.7037		
Total	35	1094.5809			

A20: ANOVA for the effect of plant media and variety on Nitrogen at 22 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	0.00545000	0.00272500	10.80	0.0005
Variety	1	0.00054444	0.00054444	2.16	0.1560
Spacing	5	0.00166667	0.00033333	1.32	0.2917
Variety*Spacing	5	0.00328889	0.00065778	2.61	0.0536
Error	22	0.00555000	0.00025227		
Total	35	0.01650000			

A21: ANOVA for the effect of plant media and variety on stalk diameter 57 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.00153	0.00076	0.05	
Spacing	5	0.34848	0.06970	4.59	0.005
Variety	1	0.70533	0.70533	46.47	<.001
Spacing*Variety	5	0.09416	0.01883	1.24	0.324
Residual	22	0.33389	0.01518		
Total	35	1.48338			

A22: ANOVA for the effect of plant media and variety on total number of millable cane ha^{-1} 57 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	6.64	3.32	0.22	
Spacing	5	4304.85	860.97	55.93	<.001
Variety	1	23657.37	23657.37	1536.88	<.001
Spacing*Variety	5	480.33	96.07	6.24	<.001
Residual	22	338.65	15.39		
Total	35	28787.84			

A23: ANOVA for the effect of plant media and variety on mean stalk weight (kg) 57 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.11572	0.05786	0.84	
Spacing	5	0.28667	0.05733	0.83	0.541
Variety	1	2.45662	2.45662	35.67	<.001
Spacing*Variety	5	0.14295	0.02859	0.42	0.833
Residual	22	1.51533	0.06888		
Total	35	4.51730			

A24: ANOVA for the effect of plant media and variety on cane yield (tons ha^{-1}) WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	322.0	161.0	0.35	
Spacing	5	3956.1	791.2	1.73	0.169
Variety	1	1242.5	1242.5	2.72	0.113
Spacing*Variety	5	1182.5	236.5	0.52	0.760
Residual	22	10041.1	456.4		
Total	35	16744.2			

A25: ANOVA for the effect of plant media and variety on sugar yield (tons ha^{-1}) WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.07	0.03	0.00	
Spacing	5	106.62	21.32	1.95	0.127
Variety	1	36.52	36.52	3.33	0.082
Spacing*Variety	5	13.73	2.75	0.25	0.935
Residual	22	241.09	10.96		
Total	35	398.03			

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