KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY (KNUST)

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DEPARTMENT OF CROP AND SOIL SCIENCES

ASSESSMENT OF WEED MANAGEMENT STRATEGIES ON CASSAVA (*Manihot esculenta* Crantz) GROWTH AND YIELD IN GHANA.

BY

DAN DAVID QUEE

MSc. Crop Protection (Weed Science)

Njala University - Sierra Leone.

JUNE 2015

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A THESIS SUBMITTED TO THE DEPARTMENT OF CROP AND SOIL SCIENCES, FACULTY OF AGRICULTURE, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA, IN PARTIAL FULFULMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE, MASTER OF PHILOSOPHY IN AGRONOMY (WEED SCIENCE).

JUNE 2015

DECLARATION

I hereby declare that this submission is my own research work towards the Master of Philosophy (MPhil) and that to the best of my knowledge, it contains no material previously published by another person which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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ABSTRACT

A field experiment was conducted at the Kwame Nkrumah University of Science and Technology Kumasi, Ghana, between May, 2014 and May 2015 cropping season to assess weed management strategies on cassava (*Manihot esculenta* Crantz) growth and yield. The experiment was set up as a 6 x 2 factorial arranged in a randomized complete block design replicated four times. The treatments consisted of two cassava varieties- Ampong (Early branching) and Dokuduade (late branching). Six weed control methods studied were: application of Butachlor at 4l/ha + 2 hoe-weedings, Terbulor at 4l/ha + 2 hoe-weedings, three-time manual hoe-weedings, three-time manual cutlass-weedings, weed-free and weedy checks treatment. The predominant weed species were *Tridax procumbens, Mimosa pudica, Euphorbia heterophylla, Croton hirtus, Spigelia anthelmia, Digitaria ciliaris, Centrosema pubescens*, *Brachiaria deflexa* and *Panicum maximum* consisting 85% weed density in the field. Ampong variety was superior in growth and yielded greater than Dokuduade variety on an average of 9.65 and 8.49 respectively. Hoe weeding was more effective than cutlass weeding in controlling weeds under cassava. Among the weeding treatments studied, Terbulor at 4l/ha + 2 hoe-weedings had significantly maximum effective weed control which resulted in over 91% tuber root yield. Additionally, the Terbulor at 4l/ha + 2 hoe-weeding had significantly higher net revenue (6,899.18 GH¢/ha) than weed-free (5,735.97 GH¢/ha) and weedy (1,807.85 GH¢/ha). Thus, the application of Terbulor at 4l/ha + 2 hoe-weeding seemed most appropriate for weed control in cassava fields.

DEDICATION

This thesis is dedicated to my late father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

I owe a special gratitude to Mr. and Mrs. Edmond Anthony, whose words of encouragement, push for tenacity ring in my ears and have never left my side and are very special. I also dedicate this thesis to my wife, Lucy Quee and our children who have supported me throughout the process and will always appreciate all they have done.

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I would like to acknowledge and thank members of staff of the Weed Science Division of the Crops Research Institute (CRI) for providing the assistance requested and their continued support.

I thank my mother for her love and support throughout my life. Thank you for giving me strength to reach for the stars and chase my dreams. My sisters, brothers, auntie and cousins deserve my wholehearted thanks as well. Special thanks to my wife, Lucy Quee for her never ending support, staying at my side through the hardest time, and her constant moral support.

Finally, I would like to leave the remaining space in memory of Mr. David M. Quee (1923-1991), a brilliant and hardworking father.

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LIST OF ABBREVIATIONS

AB+2HW: Ampong and Butachlor + 2 Hoe-weeding

ACW: Ampong and Cutlass weeding

AHW: Ampong and Hoe-weeding

ANOVA: Analysis of Variance

AT+2HW: Ampong and Terbulor + 2 Hoe-weeding

AW: Ampong and Weedy

AWF: Ampong and Weed-free

CAD: Cassava Anthracnose Disease

CBB: Cassava Bacterial Blight

CBSD: Cassava Brown Streak Disease

CGIAR: Consultative Group for International Agricultural Research

CGM: Cassava Green Mite

CMB: Cassava Mealy Bug

CMD: Cassava Mosaic Disease

CRI: Crops Research Institute

DB+2HW: Dokuduade and Butachlor + 2 Hoe-weeding

DCW: Dokuduade and Cutlass weeding

DHW: Dokuduade and Hoe-weeding

DT+2HW: Dokuduade and Terbulor + 2 Hoe-weeding

DW: Dokuduade and Weedy

DWF: Dokuduade and Weed-frree

FAO: Food and Agriculture Organization

FAOSTAT: Food and Agriculture Organization of United Nations, Statistics Department

Freq.: Frequency

GH¢: Ghana cedis

GMR: Gross Marginal Returns

IITA: International Institute of Tropical Agriculture

LSD: Least Significant Difference

MAP: Months after Planting

MOFA: Ministry of Food and Agriculture

TVO: Total Value Output

VCP: Variable Cost of Production

CHAPTER ONE

1.0 INTRODUCTION

Cassava (*Manihot esculenta* Crantz), originally a crop of South America introduced into Africa by the Portuguese traders from Brazil in the 16th century (Adeniji *et al*., 2005), was adopted as a famine-reserve crop. The crop is cultivated in about 40 African countries, from Madagascar in the Southeast to Senegal and to Cape Verde in the Northwest. According to Nweke (2003), about 70 percent of Africa's cassava output is from Nigeria, the Congo and Tanzania. Ghana has been ranked third largest producer of cassava in Africa, producing an estimated 10 million tonnes (FAO, 2009).

In Africa, cassava plays a principal role in the food economy. Enete *et al*. (2001) noted that it provides about 70% of the daily calorie intake and 40% of all calories consumed in Africa. In Ghana, it accounts for a daily calorie intake of 30% and the crop is grown by nearly every farming family (FAO, 2006). Other uses include animal feed formulation, agro-industrial uses such as ethanol and adhesive (Iyagba, 2010). Its starch and flour are used in textiles, pharmaceutical, petroleum and brewery industries (Narina and Odeny, 2011). It is a source of income for farm households in the tropics where hunger, starvation and unemployment prevails (Ayoola and Makinde, 2007), contributing positively to poverty alleviation.

The major constraints of cassava production include, unavailability of good quality planting material, pests (insects/weeds) and disease infestations/incidence, access to labour and poor cultural practices. Also, some cassava varieties tend to have poor cooking quality especially when grown on depleted soils and therefore, cannot be mealy and pounded into fufu.

However, in Africa, government intervention and the efforts of non-governmental organizations in the cassava subsector have made progress in genetic improvement, agronomic practices, pests and disease control management, though with minimal emphasis on weed management (IFAD and FAO, 2005). One key challenge to increasing crop production and improving farmer's lives is poor weed management. Weeds cause about $ 95 billion/year of food production losses and 70% of this loss is from poor countries (FAO, 2009).

Slow initial development of sprouts makes cassava susceptible to weed competition immediately after planting, which can affect canopy development, tuber formation, tuber number and weight, and serve as alternate host to pests and diseases.

Hand weeding, the most widespread method of weed control is most often not achieving maximum productivity. Hand weeding has drawbacks as the operation is tedious, slow, labour intensive, and expensive. Smallholder farmers spend 50-70% of their total labour time weeding (Chikoye *et al*., 2007). Labour supply for agricultural production has declined and this is attributed to factors such as rural-urban migration, increased enrolment in school, increased employment opportunities accompanying industrialization, as well as increased off farm employment.

The readily available and reliable cheap labour force in West Africa has disappeared due to rapid urbanization, improved living standards, and increased educational opportunities. The use of weed management practice that can reduce this labour requirement thereby reducing the cost of food production has been emphasized (Ekeleme *et al.*, 2003).

The use of herbicides for weed control in cassava has been proven to be cheap if applied timely and correctly (Chikoye *et al.*, 2001). Also selective herbicide for cassava exist but only very few are available on the market in Ghana. In addition, most farmer's practice intercropping system in which selective herbicide for one crop may not be suitable for the other component crop (s).

The development of a comprehensive management strategy for weeds should be a priority research because weeds threaten the livelihood of smallholder farmers in West Africa. It is also important to have information and knowledge on weeds perceived to be noxious, and how their control affects cost of production and crop yields for a country where most of the farmers are peasants.

The increased dependence on cassava as a source of food and raw material for industries in the tropics has led to cultivation of large hectares. Without adequate weed control, the use of other improved cultural practices will generally lead to low yields, hence the need for development of sustainable methods of weed control. Therefore, the ultimate aim of this research was to assess efficient and profitable weed management strategies to improve cassava productivity.

The specific objectives of this study were to:

i. Compare the effectiveness of different weed control methods in cassava.
ii. Evaluate the potential and efficacy of herbicides and its effect on cassava tuber cooking quality.
iii. Determine weed control efficiencies on growth and yield of cassava.
iv. Evaluate the economic profitability of the various weed control measures.
v. Compare the performance of two cassava morphotypes under different weed control methods.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin, Diversity and Taxonomy of Cassava

Cassava (*Manihot esculenta* Crantz ssp. esculenta) originated from wild subspecies *M. esculenta* ssp. Flabellifolia (Roa *et al*., 2000). According to Allem (2002), *M. esculenta* ssp. flabellifolia plants were originally collected from the wild, domesticated and multiplied by vegetative propagation along the southern border of Amazon basin. Similarly, Olsen and Schaal (2001) confirmed a southern Amazonian domestication site. Central Brazil, with its large number of wild Manihot species, is likely the primary centre of diversity of cassava (Nassar, 2002). In the 16th century, the Portuguese brought domesticated varieties of cassava from Brazil to West Africa, from where it spread across the sub-Saharan region (Hillocks, 2002; Okogbenin *et al.*, 2007). It was also introduced to most of Asia and the Pacific in the late 18th and early 19th centuries (Onwueme, 2002). The taxonomic hierarchy of cassava is:

- Order: Malpighiales
- Family: Euphorbiaceae
- Genus: Manihot
- Species: *Manihot esculenta* Crantz
- Subspecies: *Manihot. esculenta* Crantz ssp. esculenta, *Manihot. esculenta* Crantz ssp. flabellifolia (Pohl) Cifferi, and *Manihot. esculenta* Crantz ssp. peruviana (Müeller) (Allem, 2002).

2.2 Production and Importance of Cassava

Cassava is mostly produced by subsistence farmers in the humid and sub-humid tropics. Africa accounted for 54%, Asia for 28% and Latin America and the Caribbean for 19% of the total world production of cassava (IITA, 2002). Africa is the largest producer of cassava with Asia as the second largest and then followed by the Americas (FAOSTAT, 2010). Nigeria, Thailand, Brazil, Indonesia, and the Democratic Republic of the Congo are the leading cassava producing countries (FAO, 2009). Production in West Africa roughly doubled from 25.8 million tons to 52.3 million tons in 2004 (FAO, 2006). Nigeria is the largest producer, producing 38 million metric tons in 2010 (CGIAR, 2011) and leading the world with 19% of global market share (Hillocks, 2002). Ghana is the third largest producer of cassava in Africa (FAO, 2006), and currently produces about 12,260,000 MT of cassava annually (MOFA, 2009).

According to Nweke *et al*. (2002), cassava plays five important roles in African development: famine-reserve crop, rural staple food, cash crop for both rural and urban households and raw material for feed and chemical industries. Cassava (*Manihot esculenta* Crantz) is currently the sixth most important food crop in the world, which plays a principal role in the food economy in terms of energy consumed (FAO, 2008). It can serve as a source of income for farm households (Adjei-Nsiah *et al.*, 2012), used in agro-industries for the production of starch, ethanol, adhesive and glucose syrup (Iyagba, 2010). Its starch and flour are used in food, textiles, pharmaceutical, petroleum, plywood, paper and brewery industries (Narina and Odeny, 2011).

2.3 Constraints in Cassava Subsistence Agriculture

Weed infestation is a major constraint in cassava production, and it is most labour demanding field operation because the crop is susceptible to weed infestation due to its initial slow growth after planting (Alabi, 1997). According to Dixon *et al.* (2003), pests and diseases infestation on cassava in Africa leads to yield reduction, thus loss of food and income for the farming communities. The most important economic pests which feed on the leaves thereby reducing the crop's photosynthetic ability are Cassava Green Mite (CGM), Cassava Mealy Bug (CMB) and the African variegated grasshopper (Poubom *et al.,* 2005). Also the most significance diseases are Cassava Mosaic Disease (CMD), Cassava Brown Streak Disease (CBSD), Cassava Bacterial Blight (CBB), root rot and Cassava Anthracnose Disease (CAD) (Poubom *et al.,* 2005). However, some of these biotic constraints have been addressed through the use of biological agents or breeding for resistant varieties (Bellotti, 2002; Calvert and Thresh, 2002; Hillocks and Wydra, 2002).

Smallholder farmers practice low input cassava production due to poor access to fertile soil, quality planting materials and technology. Subsistence cassava farmers lack adequate postharvest facilities and essential infrastructure such as roads, means of communication, and input supply systems. These postharvest and market constraints in the tropics significantly lead to the situation that any surplus beyond the immediate home consumption becomes waste or manure (Dixon *et al.,* 2003). The intervention of government and non-governmental organizations in the cassava subsector have led to a number of measures that support the production, processing and marketing of cassava.

2.4 Origin and Evolution of Weeds

Agricultural weeds are plants that are undesirable, competitive, persistent and damaging, interfering with the activities or welfare of human beings (Vencil, 2002). There are approximately 250,000 species of plants worldwide; of these, about 3% behave as weeds (Dwight, 2015). The most common pattern for the origin of agricultural plants is the inter-fertile wild-crop-weed (w-c-w) plant complex in which both crop and weed were derived from the same wild progenitor species (Dekker, 2011). Weeds developed through disturbance of human activities and as a result of the products of hybridization between wild domestic races of crop plants (Dekker, 2011).

2.5 Impact of Weeds in Cassava Farms

Weeds are one of the major serious problems to cassava farmers in Ghana, because they destroy the natural surroundings, plants, animals, rivers and forests by aggressively competing for nutrients, space, water and sunlight. Weeds overcome plants excellently because they grow faster than native plants and can survive and reproduce in disturbed environments.

Weeds harm cassava mainly because they grow abundantly, vigorously, rapidly and completely cover the ground surface than cassava if not controlled in time, thus utilize lots of nutrients and water from the soil making these materials unavailable for plant growth. For example, *Mimosa invisa* and *Chromolaena odorata* occupies inter-rows and shade cassava plants from sunlight. Weeds such as *Cuscuta australis* grow and feed directly on cassava stems by sucking water and nutrients from the plant.

Weeds can reduce crop yield and quality (Willis, 2010; Khanh *et al*., 2007). For example, *Imperata cylindrica* sometimes pierce and destroy cassava storage roots and provides entry for rot-causing pathogens (Khanh *et al.*, 2007). The level of disturbance of weeds in the cassava crop may decrease the production of roots and starch from 89.8 to 100% (Johanns and Contiero, 2006; Albuquerque *et al*., 2008; Biffe *et al*., 2010). Also, *Mimosa invisa* is difficult to remove by hand weeding or hoeing because its thorns scratch and cause wounds, while *Mucuna pruriens* and several hairy weeds cause intense itching.

Some weeds serve as alternate hosts for many plant pests and diseases. For instance, *Cyperus rotundus* serves as alternate host to nematodes and athropods. Also *Chromolaena odorata* become alternate host to immature stages of *Zonocerus variegatus* which destroy cassava plants as they become mature grasshoppers (Yandoc-Ables *et al.*, 2006). Weeds increase cost of production (Bangsund *et al.*, 2001), thus reduces productivity, degrade and devalue land, poison stock and threaten Ghana's biodiversity and native plant communities.

Despite the negative impacts, weeds may provide benefits to agricultural crops, animals, and human. Some weeds reduce the effect of erosion by producing protective cover, helps in nutrient recycling through decay of vegetative part, provision of food/vegetables for humans e.g. leaves of *Talinum triangulare*, and tubers of *Colocasia esculentus;* medicinal use e.g. neem *(Azadirachta indica). Ageratum conyzoides* plays a major role in carbon recycling through carbon sequestration (Hillocks, 1998).

2.6 Spread of Weeds in Cassava Farms.

Weeds spread faster immediately after land preparation because they establish, reproduce and grow very quickly than other crops. Common weeds in cassava mostly spread by seeds, rhizomes, stolons, tubers, stems and roots. Annual weeds such as *Chromolaena odarata*, *Tridax procumbens*, *Euphorbia heterophylla* and *Ageratum conyzoides* are spread by seeds. *Imperata cylindrica* weeds are spread by rhizomes because their stems run underground horizontally to the soil surface, and each piece cut is capable of growing into a new plant. Sedges such as *Cyperus* and *Mariscus* species are spread through tubers, and each piece of the tuber contains a bud which is capable of growing into a new weed plant. Weeds are likely to spread by stolons if cut into pieces during land preparation. For instance, each piece of *Cynodon dactylon* can grow into a new weed plant because it reproduces very long stolons. Also, weeds spread through stem cuttings and basal shoot stocks; examples are *Commelina benghalensis* and *Talinum triangulare* (IITA, 2000).

2.7 Weed-Crop Interactions

Weed problems are severe in tropical African regions because they grow vigorously and regenerate rapidly due to heat, higher light intensity, high humidity and temperature (Akobundu, 1980). Njoku (1996) indicated that over 286 species of these common weeds have been identified in crop fields of some West African countries. Out of these total, Chikoye and Ekeleme (2001) stated that 263 weed species belonging to 38 families are found in crop fields in West Africa of which 72% are broadleaved weeds, 24% grasses and 4% sedges.

Several researchers have proved that weeds strongly compete with cassava and causes total yield losses if not controlled. Cassava is susceptible to weeds soon after planting because of its initial slow growth rate. According to Nyam (2005), crop losses of up to 100% was due to absence of weed control in crop farm and caused an average yield gap of 5t/ha (Fermont *et al*., 2009). In addition, cassava requires 84 days weed-free after planting because the crop is most sensitive to weed interference during this period (Obuo *et al*., 1999).

2.8 Common Weeds in Cassava Farms

Many kinds of weeds occur in particular places. The following are selections of the most widespread species of weeds in cassava farms. Grasses such as *Imperata cylindrica*, *Cynodon dactylon, Panicum maximum, Andropogon spp., Pennisetum purpureum, Axonopus compressus* and *Pennisetum polystachion* are commonly found affecting cassava production (IITA, 2000). The common sedges, which have solid and triangular shaped stems, causing problems in cassava farms are *Mariscus alternifolius*, and *Cyperus rotundus* (IITA, 2000). Some broadleaved weeds found in cassava farms are *Chromolaena odorata*, *Centrosema pubescens*, *Euphorbia* *heterophylla*, *Tridax procumbens*, *Commelina benghalensis*, *Sida acuta*, *Mimosa pudica*, *Talinum triangulare*, *Amaranthus spinosus* and *Ageratum conyzoides* (IITA, 2000).

2.9 Weed Control in Cassava Fields

The control of weeds is one of the most important operations in cassava production that should be effectively and efficiently carried out to ensure desired production and productivity increases for improved livelihoods and welfare. According to IITA (2007), 50% reduction in the yield of cassava was due to late and insufficient weeding. Thus weed control efficiency and efficacy is one strategy that will ensure food production. Resource poor peasant farmers employ various weed management practices that combat weed infestation and improve cassava productivity. These include preventive, physical, cultural, biological, chemical and integrated control measures.

2.9.1 Cultural Weed Management

Cultural weed control measures refer to good crop husbandry used to minimize the action of weeds interfering with crops, which includes mulching, crop variety, sowing/planting time and crop spatial management, cover crop (used as living mulches), inter-cropping and crop rotation.

Rotating crops is to discourage the growth of weeds adapted to a particular crop. It involves cultivating specific crops to control problem weed, partly due to different dates of crop maturity, harvest and canopy cover over a longer period. Thus, crops suffer most from weeds that share similar growth patterns; for example, Shepherd’s-purse thrives in fields of wheat because its life cycle is identical to that of the grain, thus rotating crops with different nutrient and management requirements in the same field will disrupt weed life cycles (Cardina *et al*., 2002).

Roots and tuber crops should be planted early to get established and successfully compete with weeds that germinate later. Weeds removed before and after critical periods do not cause any appreciable yield loss. According to Johnson and Frick (2012), early weed removal was found necessary to protect pea yield.

Weeds are suppressed through natural means by manipulating plant population, spatial arrangement, type of plant cultivar and ground cover management. Egusi melon (live mulch) planted in a very close spacing before cassava reduced weed infestation in cassava farms and also buckwheat (smother crop) grew rapidly and produced dense canopy which slows weed establishment (IITA, 2007). According to Moosavi *et al.* (2005), increase in bean density from 20 to 30 and 40 plants m^{-2} can cause an increase in the threshold of economic damage of redroot pigweed from 0.5 to 1 and 2.7 plants m^{-2}.

2.9.2 Prevention

Preventive measures involve strategies necessary to prevent the introduction of new weed species into a given geographical area as well as the multiplication and spread of existing weed species capable of inflicting upon the resources and values of society. Weed prevention involves fallowing, preventing weeds from setting seeds, use of clean planting material and machinery/tools for planting, and quarantine laws services.

2.9.3 Mechanical (Physical)

Hand weeding is the most common means of weed control practiced on smallholder farms and consists of hand-pulling, hand-slashing and hoeing because they are more easily available and affordable although have consistently proved inefficient, drudgery and costly (Vissoh *et al.*, 2004). According to Ukeje (2004), women contribute more than 90% of the hand weeding labour for most crops, while 69% of children between the ages of 5-14 are used in the agricultural sector especially at peak period of weeding (Ishaya *et al*., 2008). Constraints limiting the effectiveness of hand weeding include limited money to hire labour, unavailability of labour, migration of able men to urban areas, sickness or fatigue and pregnancy (Orr *et al*., 2002; Vissoh *et al*., 2004).

Tillage can control perennial and woody weeds and buries weed seeds to reduce emergence of some weeds such as *Ipomoea spp, Commelina benghalensis, Cyperus rotundus*, *Sida acuta, Mimosa pudica*, and *Centrosema pubescens*.

2.9.4 Biological Weed Management

Biocontrol agents, especially insects, such as *Cyrtobagous salviniae* and *Calligrapha pantherina* were used to control weeds like *Salvinia molesta* and *Sida acuta* (Day *et al.,* (2005). Brady and Weil (2002) reported that living mulch functions as a weed control tool through competition for resources and light. Examples of non-food crops used as "live mulches" are *Mucuna pruriens*, *Canavalia ensiformis* which are effective against *Imperata cylindrica* and other noxious weeds (IITA, 2007). Egusi melon (*Citrullus* c*olocynthis*) and sweat potato are also crops which when intercropped, provide early ground cover and shade out weeds. Improved cassava varieties effectively suppress weeds early because they have vigorous growth, cover the ground rapidly and are competitive against weeds. They also develop lots of branches and leaves which form thick canopy to suppress and prevent weeds (IITA, 2007).

Okeleye and Salawu (1999) recommended that intercrop of cassava and melon is an effective means of controlling weeds in cassava plots, while Nwagwu *et al.* (2000) have also recommended the use of melon in cassava to control weeds. According to Ibeawuchi (2007), yam / cassava – based cropping system with four crop combinations, suppressed weeds better than most other cropping systems with two or three crop combinations.

2.9.5 Chemical Weed Control

Several herbicides have been evaluated for weed control in cassava worldwide with varying degrees of success. According to Overfield *et al*. (2001), less than 5% use of herbicide is adopted by smallholder farmers in Africa. Weed control is more easily achieved when herbicides are applied to young, actively growing weeds and their effectiveness is influenced by edaphic and climatic factors, weed flora, rate of herbicide applied, crop variety and management practices. Excellent alternative to manual weed control in cassava cultures is the use of herbicides because it is cheaper, faster and gives better weed control (Chikoye *et al*., 2005).

The use of herbicides by smallholder farmers in Ghana have been on the increase recently. Ekboir *et al.,* (2002) and Bolfrey-Arku *et al.* (2006) reported that 4% of groundnut growers use herbicides to control weeds in Ghana. According to Iyagba and Ayeni (2000), *Chromolaena odorata* and *Panicum maximum* in cassava plots were controlled by using fluazifop-butyl (0.75 kg a.i. /ha) followed by bentazon (2.0 kg a.i. /ha) at 21 days after planting. Chikoye *et al*. (2005), also reported complete and good control of weeds by new formulation of atrazine and metolachlor (Primextra). However, although the technology is cost effective and yield higher returns than manual weeding methods, major constraints attributed to herbicide use in Africa are poor mechanism to disseminate and inadequate knowledge of smallholder farmers as to which herbicide to use in a particular weed-crop situation; unavailability of herbicides and poor time of application; scarcity of extension services and trained personnel in weed science (Mavudzi *et al*., 2001; Muthamia *et al*., 2001).

2.9.6 Integrated Weed Management

It is a combination of two or more control methods at low input levels to keep weed competition in a given cropping system below an economic threshold and the approach is particularly appropriate for cassava production in the tropics where the farmers have limited resources. This involves a combination of preventive, cultural, chemical, biological and physical methods. Use of low growing crops such as fluted-pumpkin with cassava reduced the three times suggested weeding regime in cassava at 3, 8 and 12 WAP to two weeding regimes at 3 and 8 WAP by manipulating the plant population of fluted pumpkin to 26,667 plants/ha and cassava at 10,000 plants/ha (Iyagba, 2005). Other studies have also addressed intercropping as an option for an integrated weed management, particularly in farming systems with low external inputs (Schoofs and Entz, 2000). The best way to control weeds in a cassava farm is to combine different cultural practices, especially at land clearing, seedbed preparation, planting and post-planting stages of growing the crop.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of Experimental Site

The experiment was carried out in the field at Plantation Crops Section of the Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology, Kumasi from May 2014 to May 2015. It falls within latitude 06^0 $43^'$ North and 01^0 $36^'$ West (Adoa, 2009). The experimental area was previously cultivated to various crops including maize (*Zea mays* L.), garden egg (*Solanum melongena*) and cassava (*Manihot esculenta* Crantz), but left to fallow for about one year prior to commencement of the experiment. Rainfall distribution pattern of the area is bimodal; with major peak between May and mid-August and minor peak between September and mid-November. The climatic weather conditions observed during the experimental period were, mean annual temperature of 28.9^0 C, 1450 mm rainfall and relative humidity of 84.4%. The soil chemical characteristics observed of 0-30 cm depth before commencement of the experimental trials were: % Organic carbon = 1.06; % Organic matter = 1.82; Total % of Nitrogen = 0.08; K (cmol/kg) = 0.10; Available P (mg/kg) = 5.10 and pH = 6.2.

3.2 Experimental Design and Treatments

The experiment was set up as a 6 x 2 factorial arranged in a randomized complete block design (RCBD) with four replications. Each plot size measured 4 m x 6 m with a space of 0.5 m between plots and 1 m between each block, which gave a total of 48 plots in an area of 53.5 m x 27 m (1444.5 m^2 or 0.14445 ha). The plant spacing used was 1 m x 1 m, with a target plant population density of 10,000 plants/ha.

Two varieties of cassava (Ampong and Dokuduade) and six weed control methods (Hoe-weeding, cutlass weeding, weed-free, Terbulor + 2 hoe-weeding, Butachlor + 2 hoe-weeding and weedy) were evaluated.

The “Ampong” variety is short with trichotomous branching, its root yield ranges between 40-50 t/ha, dry matter content is 36%, and it is mostly used for flour, fufu and starch. This variety matures within 12 months after planting, apical leaves are dark green in colour, storage root is brown, leaves dark green, petiole red, resistant to mosaic disease and stem colour is dark brown. The “Dokuduade” variety is tall, less branching and has dichotomous branching habit, maturity period is 12 months. The root shape is irregular, storage root light brown, apical leaves light green, petiole yellowish, leaves light green and the stem has silver colour. Fresh root yield ranges between 35-40 t/ha, has low cyanide, with 30% dry matter and resistant to mosaic disease.

The second factor was the weed control regimes, which included:

(i) Hoe weeding (1, 2, and 4 MAP).

(ii) Cutlass weeding (1, 2, and 4 MAP).

(iii) Weed-free (Weeded at two weekly interval using hoe until harvest).

(iv) Terbulor 500 EC (333g/l of Metolachlor + 167g/l of Terbutryn) at a rate of 4 litres product was applied as a pre-emergent herbicide aided by 2 hand hoeing (2 and 4 MAP).

(v) Butachlor 50% EC (N-butoxymethyl-2-chloro-2', 6’-diethylacetanilide) at a rate of 4 litres product was applied as a pre-emergent herbicide aided by 2 hand hoeing (2 and 4 MAP).

(vi) Weedy until harvest.

3.3 Agronomic and Management Practices

The experimental field was slashed, disc-ploughed to the depth of about 10 - 15 cm and harrowed using tractor driven plough and harrow to loosen the soil, improve drainage, control weeds, and also increase the ease with which the crop can be harvested. Stem cuttings, each 20 cm long of both varieties (Dokuduade and Ampong), having at least four to five nodes and disease free were used as planting materials. Planting materials were obtained from the Weed Science Department, Council for Scientific and Industrial Research (CSIR), Fumesua-Kumasi. One stake per stand was planted slanting at an angle of about 45^0. The setts were planted at a depth of about 5 - 10 cm on the flat oriented in one direction. Refilling of cassava stakes was done a month after planting.

The herbicide plots, were sprayed using two pre-emergence herbicides (Terbulor 500 EC and Butachlor 50% EC) applied at the rate of 4 litres per hectare one day after planting to minimize weed growth. A ‘CP 15 knapsack’ sprayer calibrated to deliver 200 l/ha spray solution was used for herbicide application. Manual weeding was done at 1, 2, and 4 MAP until harvest using hand hoeing and slashing as one of the weed control treatments in some plots. Earthling up was carried out to promote tuberous roots formation and prevent lodging.

3.4 Data Collection

3.4.1 Pre-Harvest Parameters

Weed Measurement

Measurements on weed biomass, weed flora and weed count were recorded at 1, 2, 3 and 4 months after planting (MAP). A metal square quadrat of dimension 0.25 m^2 (0.5 x 0.5 m) was thrown at random three times in each plot. Weeds enclosed in the 0.25 m^2 quadrat area were counted and identified according to family, species present and fresh weight determined. Weed samples collected were air dried for about a week, put into brown paper envelopes and oven (Thelco® laboratory oven) dried at 80^0 C to constant weight for 48 hours to determine dry matter using an electronic scale (Methler PE 6000).

Stand establishment and harvest population

Cassava sprouting rate and crop injury effect due to application of Terbulor 500 EC and Butachlor 50% EC pre-emergence herbicides was evaluated at 3 weeks after planting (WAP). Percentage plant establishment and harvest population was calculated as sprouted cassava stakes divided by total number of cassava stakes planted, multiplied by 100.

Plant height

Five cassava plants were randomly selected from the middle rows of each plot and the height was measured from ground level of the stem to the base of the last emerged leaf using a graduated pole.

Canopy spread

Canopy spread was assessed on five representative plants of each treatment using canopy area cross-method, the longest length of canopy spread from each edge across the plant was measured using a graduated pole. The spread along that line is the horizontal distance between those two positions.

Stem girth

Stem girth was measured 10 cm above ground level on five representative plants for each treatment using metal Vernier calipers.

Height at first branching

The height of first branch was measured from ground to the first level of branching (primary branch) using a graduated pole.

Number of branches

Branch number was recorded by counting the first primary branching and division of subsequent branches from the top of the plant.

3.4.2. Harvesting Parameters

The cassava stands were harvested by hand 12 months after planting from an area of $2m^2$ at the middle of each plot. The upper parts of the stems were cut off to about 30 to 50 cm above ground before harvest, and the rest of each plant was lifted and roots carefully cut off. Data collected were above-ground biomass, number of rotten roots, root yield, root dry matter, harvest index and sensory evaluation of cooking quality. Average yield in tonnes per ha was calculated by FAO (2006) as:

$$\frac{\text{Root weight (kg)} \times 10{,}000\ m^2}{\text{Area harvested } (m^2)}$$

Dry matter and harvest index determination

Harvested plants were separated into roots, stems, stalks, foliage and weighed. Sub-samples of fresh storage roots harvested was taken for dry matter determination. Dry matter percentage of roots were determined from a random bulk sample of nine plants selected from the inner rows. The roots were peeled and cut into thin pieces after washing. 100 grams of fresh root was chopped in the form of chips and dried at 80°C for 48 hours in a Thelco® laboratory oven. The dried samples were then weighed to obtain the dry weights, and dry matter percentage was calculated by FAO (2006) as:

$$\frac{\text{Dry root weight}}{\text{Initial wet weight}} \times 100$$

Harvest index was determined by FAO (2006) as:

$$\frac{\text{Fresh root weight}}{\text{Above-ground biomass + fresh root weight}}$$

Sensory evaluation of cooking quality

The roots were randomly selected from the 2 m^2 area harvested from each plot, peeled, washed, cut into cubes and cooked in boiling water for about 45 minutes. Some portions of all the sampled cooked roots were pounded into a paste as fufu is prepared in Ghana. Cooking quality test was done by a sensory evaluation panel, consisting of ten regular cassava and fufu consumers. The parameters considered for cooking quality were mealiness, elasticity and poundability. A scoring system of 1 – 4 scale was used for all cooking quality parameters as indicated below.

Score	Poundability	Elasticity	Mealiness	Lumpiness
1	Not Poundable	Not Elastic	Not Mealy	Not Lumpy
2	Moderately Poundable	Moderately Elastic	Moderately Mealy	Moderately Lumpy
3	Poundable	Elastic	Mealy	Lumpy
4	Very Poundable	Very Elastic	Very Mealy	Very Lumpy

Economic benefits

Economic assessment of the various weed management strategies were evaluated using costs and returns computed to determine the net revenue (profit) from the use of different weed control methods (Okoruwa *et al*., 2005).

- Gross revenue (GR) was calculated as: Root yield (t/ha) x Current market price of root (GH¢/ha).
- Net revenue or profit (NR) was calculated as: Gross revenue (GH¢/ha) – Total cost of production.
- Marginal rates of return (MRR) = $\frac{\text{Change in net revenue}}{\text{Change in total cost of production}} \times 100$

3.5 Data Analysis

The data was subjected to analysis of variance (ANOVA) using the Genstat 12th edition statistical software package. The Least Significant Difference (LSD) test was used to compare all treatments means at 5% level of probability. Weed assessment data was analyzed by transformation using log base 10 (Log_{10}).

CHAPTER FOUR

4.0 RESULTS

4.1 Cassava Stand Establishment and harvest population

Results showed significant differences ($P < 0.05$) among variety and weed management strategies for stand establishment and harvest population (Table 4.1). Plant establishment for the Ampong variety was significantly higher than that of Dokuduade. The weed-free treatment effect supported the highest stand establishment (37.86%) at 1 month after planting, which was significantly higher than all other treatment effects. In addition, harvest population under Terbulor + 2 hoe-weeding was also significantly ($P < 0.05$) higher than the other treatment effects at 11 months after planting. Plant establishment and harvest population in the weedy treatment was the poorest. The difference between hoe weeding and cutlass weeding treatments at 11 MAP were not significant.

Table 4.1: Influence of variety and weed management strategies on stand establishment and harvest population of cassava, 2014-2015.

Treatment	**Stand establishment (%)**	**Harvest population (%)**
	1 MAP	**11 MAP**
Variety		
Dokuduade	8.69	75.60
Ampong	36.07	85.24
LSD (5%)	**2.69**	**3.46**
Weed control treatments		
Hoe-weeding	22.14	80.71
Cutlass weeding	16.79	77.14
Weed-free	37.86	86.79
Butachlor + 2 hoe-weeding	27.14	83.93
Terbulor + 2 hoe-weeding	28.93	90.00
Weedy	1.43	63.93
LSD (5%)	**4.67**	**5.99**
CV (%)	**20.5**	**7.3**

4.2 Canopy Spread

The Ampong variety had significantly greater ($P < 0.05$) canopy spread than Dokuduade on all sampling periods (Table 4.2). For the weed control methods, canopy spread in the weed-free treatment was greater on all sampling days, and these effects were significantly higher ($P < 0.05$) than those other treatment effects. Additionally, at each sampling occasion, the weedy control effect was significantly lower ($P < 0.05$) than all other treatment effects. Statistically, there was no significant difference between hoe-weeding and cutlass-weeding on all sampling days. Between the two herbicide treatments, the treatment effects of the Terbulor + 2 hoe-weeding was significantly higher ($P < 0.05$) than that of Butachlor + 2 hoe-weeding on all sampling occasions, except the 3 MAP sampling.

Table 4.2: Effect of variety and weed management strategies on canopy spread of cassava, 2014-2015.

Treatment	**Canopy spread (m)**					
	1 MAP	**2 MAP**	**3 MAP**	**4 MAP**	**5 MAP**	**6 MAP**
<u>Variety</u>						
Dokuduade	0.78	1.00	1.27	1.66	1.82	1.99
Ampong	0.92	1.08	1.38	1.79	1.93	2.09
LSD (5%)	**0.02**	**0.03**	**0.03**	**0.04**	**0.05**	**0.06**
<u>Weed control treatments</u>						
Hoe weeding	0.84	1.03	1.32	1.67	1.86	2.03
Cutlass weeding	0.80	0.99	1.30	1.62	1.79	1.94
Weed-free	0.97	1.18	1.45	1.96	2.09	2.22
Butachlor + 2 hoe-weeding	0.87	1.06	1.39	1.76	1.91	2.11
Terbulor + 2 hoe-weeding	0.92	1.13	1.40	1.89	2.02	2.23
Weedy	0.69	0.86	1.09	1.46	1.59	1.71
LSD (5%)	**0.04**	**0.05**	**0.06**	**0.08**	**0.09**	**0.11**
CV (%)	**5.7**	**5.3**	**4.9**	**4.6**	**4.8**	**5.4**

4.3 Plant Height

Both variety and weed control treatments had significant ($P < 0.05$) effect on plant height all days of sampling (Table 4.3). Plant height was significantly greater in Dokuduade than Ampong variety on all sampling days. For weed management strategies, plant height in the weed-free treatment was the greatest on all sampling days, and this was significantly higher than all other treatment effects on all days, except at 2 and 3 MAP. On these 2 sampling occasions, the weed-free treatment was significantly higher than all other effects, except that of Terbulor + 2 hoe-weeding treatment only. On all days of sampling, the weedy-check treatment effect was significantly lower than all other treatment effects. The treatment effects of the hoeing and cutlassing were similar, except at 1 and 5 MAP where the plants in the hoeing treatment were taller than the cutlass treatment.

Table 4.3: Effect of variety and weed management strategies on height per cassava plant, 2014-2015.

Treatment	**Plant height (m)**					
	1 MAP	**2 MAP**	**3 MAP**	**4 MAP**	**5 MAP**	**6 MAP**
Variety						
Dokuduade	0.33	0.82	1.32	1.71	1.87	2.01
Ampong	0.30	0.64	1.05	1.35	1.50	1.61
LSD (5%)	**0.01**	**0.03**	**0.04**	**0.04**	**0.05**	**0.06**
Weed control treatments						
Hoe weeding	0.31	0.71	1.16	1.48	1.65	1.75
Cutlass weeding	0.27	0.67	1.11	1.42	1.55	1.70
Weed-free	0.40	0.90	1.33	1.74	1.91	2.11
Butachlor + 2 hoe-weeding	0.34	0.76	1.21	1.58	1.74	1.84
Terbulor + 2 hoe-weeding	0.35	0.84	1.31	1.64	1.79	1.92
Weedy	0.21	0.52	0.97	1.32	1.46	1.56
LSD (5%)	**0.02**	**0.06**	**0.08**	**0.08**	**0.09**	**0.10**
CV (%)	**8.3**	**8.9**	**6.7**	**5.4**	**5.3**	**5.9**

4.4 Height at Primary Branching

The branch height was significantly higher in Dokuduade than Ampong variety throughout the sampling periods (Table 4.4). For the weed control methods, branch height in the weed-free treatment was significantly higher ($P < 0.05$) than all other methods on all sampling days, except the Terbulor + 2 hoe-weeding treatment effect from 1-5 MAP. At 6 MAP, the weed-free treatment effect was significantly higher than all other treatment effects. Between the two herbicide treatments, the treatment effect of the Terbulor + 2 hoe-weeding was significantly higher than that of Butachlor + 2 hoe-weeding on all sampling days, except at 5 MAP. The hoeing only and cutlass weeding treatment differences were not significant on all sampling days, except at 6 MAP, where the hoe treatment effect was greater than the cutlass treatment. On all sampling days the weedy check treatment effect was significantly lower than all other treatment effects.

Table 4.4: Effect of variety and weed management strategies on branch height per cassava plant, 2014-2015.

Treatment	**Branch height (m)**				
	2 MAP	**3 MAP**	**4 MAP**	**5 MAP**	**6 MAP**
<u>Variety</u>					
Dokuduade	0.54	0.73	0.76	0.78	0.89
Ampong	0.39	0.44	0.47	0.48	0.50
LSD (5%)	**0.04**	**0.01**	**0.02**	**0.02**	**0.02**
<u>Weed control treatments</u>					
Hoe weeding	0.44	0.56	0.58	0.60	0.62
Cutlass weeding	0.40	0.53	0.56	0.57	0.58
Weed-free	0.64	0.67	0.70	0.73	0.75
Butachlor + 2 hoe-weeding	0.50	0.60	0.64	0.66	0.67
Terbulor + 2 hoe-weeding	0.59	0.65	0.68	0.69	0.71
Weedy	0.22	0.50	0.53	0.55	0.56
LSD (5%)	**0.07**	**0.03**	**0.03**	**0.04**	**0.03**
CV (%)	**16.5**	**5.7**	**6.1**	**6.3**	**6.0**

4.5 Number of Branches per Plant

Results of branch number showed varietal differences with Ampong variety recording significantly higher branches than Dokuduade at all measurement periods (Table 4.5). Weed control treatment effects were different throughout the sampling periods, the weedy control treatment effect was significantly lower than all other treatment effects on all days of sampling. The Weed-free treatment effect was greatest throughout the sampling periods and had significantly higher number of branches than all other treatment effects at 4, 5 and 6 MAP. At both 2 and 3 MAP samplings, the weed-free treatment effect was greater than all other treatment effects, except the Terbulor + 2 hoe-weeding treatment. On all sampling days the effect of the 2 herbicides + 2 hoe-weeding treatments were not different from one another. Additionally, treatment differences between hoeing only and cutlass weeding were not significant at all periods of sampling.

Table 4.5: Effect of variety and weed management strategies on number of branches per cassava plant, 2014-2015.

Treatment	**Number of branches**				
	2 MAP	**3 MAP**	**4 MAP**	**5 MAP**	**6 MAP**
Variety					
Dokuduade	1.98	3.07	8.50	17.21	18.81
Ampong	2.82	5.96	12.30	20.19	21.44
LSD (5%)	**0.23**	**0.33**	**0.88**	**0.87**	**1.08**
Weed control treatments					
Hoe weeding	2.27	4.45	10.05	17.98	18.93
Cutlass weeding	2.15	4.05	9.05	16.90	18.10
Weed-free	3.00	5.52	13.38	23.55	24.90
Butachlor + 2 hoe-weeding	2.60	4.82	10.75	19.70	21.45
Terbulor + 2 hoe-weeding	2.82	5.20	12.10	21.15	23.00
Weedy	1.57	3.07	7.07	12.93	14.38
LSD (5%)	**0.41**	**0.57**	**1.53**	**1.51**	**1.88**
CV (%)	**16.8**	**12.6**	**14.5**	**8.00**	**9.2**

4.6 Stem Girth

Both variety and weed control treatments had significant (P < 0.05) effects on stem girth of cassava at various measurement periods. Stem girth was significantly greater in Dokuduade than Ampong variety on sampling periods of the study (Table 4.6). For weed management strategies, stem girth in the weed-free treatment was significantly higher (P < 0.05) than all other treatment effects at 3 and 5 MAP only. At 2, 4 and 6 MAP, the weed-free treatment effect was significantly higher than all other treatment effects, except the Terbulor + 2 hoe-weeding treatment effect. At 1 MAP, the weed-free treatment effect was similar to the two herbicides + 2 hoe-weeding treatments, but greater than all other treatment effects. Treatment differences between the two herbicide + 2 hoe-weeding effects were similar on all days, except at 4 MAP where the Terbulor + 2 hoe-weeding effect was greater than that of the Butachlor + 2 hoe-weeding. Additionally, the hoeing only and cutlass weeding effects were not different on all days. Finally, the weedy check treatment effect was lower than all treatment effects on all days.

Table 4.6: Effect of variety and weed management strategies on stem girth of cassava plant, 2014-2015.

Treatment	**Stem girth (cm)**					
	1 MAP	**2 MAP**	**3 MAP**	**4 MAP**	**5 MAP**	**6 MAP**
Variety						
Dokuduade	1.21	1.58	2.11	2.60	2.67	2.80
Ampong	1.01	1.39	1.89	2.31	2.37	2.47
LSD (5%)	**0.05**	**0.05**	**0.08**	**0.07**	**0.07**	**0.09**
Weed control treatments						
Hoe weeding	1.12	1.47	1.94	2.41	2.48	2.58
Cutlass weeding	0.99	1.36	1.82	2.30	2.38	2.47
Weed-free	1.31	1.72	2.36	2.77	2.84	2.95
Butachlor + 2 hoe-weeding	1.18	1.57	2.05	2.52	2.59	2.74
Terbulor + 2 hoe-weeding	1.23	1.66	2.19	2.67	2.70	2.85
Weedy	0.83	1.13	1.65	2.04	2.12	2.22
LSD (5%)	**0.09**	**0.10**	**0.15**	**0.13**	**0.13**	**0.16**
CV (%)	**8.4**	**6.8**	**7.5**	**5.3**	**5.4**	**6.2**

4.7 Weed Density

Weed population was significantly higher under Dokuduade than Ampong variety, on sampling periods (Table 4.7). Plots treated with Terbulor + 2 hoe-weeding had lower weed density than Butachlor + 2 hoe-weeding treatment on all sampling days. Statistically, there were no significant difference between Terbulor and Butachlor with two supplementary hoe-weedings 1, 2 and 3 months after planting. Weed population under cutlass weeding was significantly higher than under hoeing on all days of sampling. The weedicide + 2 hoe-weeding treatments controlled weeds better than both cutlass and hoeing treatments. On all sampling days, the weedy check plots had significantly greater weed population than all other control strategies employed in the study.

Table 4.7: Effect of variety and weed management strategies on total weed population, 2014-2015.

Treatment	**Weed population/m^2**			
	1 MAP	**2 MAP**	**3 MAP**	**4 MAP**
Variety				
Dokuduade	1.50	1.68	1.69	1.88
Ampong	1.29	1.50	1.42	1.66
LSD (5%)	**0.08**	**0.05**	**0.14**	**0.12**
Weed control treatments				
Hoe-weeding	1.51	1.64	1.65	1.86
Cutlass weeding	1.72	1.88	2.03	2.13
Weed-free	-	-	-	-
Butachlor + 2 hoe-weeding	1.18	1.46	1.27	1.58
Terbulor + 2 hoe-weeding	1.15	1.28	1.09	1.47
Weedy	1.94	2.06	2.29	2.39
LSD (5%)	**0.14**	**0.10**	**0.24**	**0.20**
CV (%)	**9.8**	**6.2**	**15.2**	**11.6**

4.8 Weed Biomass

Weed dry matter was significantly higher ($P < 0.05$) under Dokuduade than Ampong variety on all sampling days (Table 4.8). Similarly, weed dry matter was significantly affected by weed control methods. The result showed that plots treated with Terbulor + 2 hoe-weeding had significantly lower weed dry matter ($P < 0.05$), except at 3 months after planting, the treatment effects between Butachlor and Terbulor with two supplementary hoe-weedings were not significant. At each sampling occasion, the weedy check treatment had the greatest weed biomass. Additionally weed biomass under cutlass weeding method was significantly higher than in the hoeing treatment on all days. Weed biomass in the herbicide + 2 hoe-weeding treatments were lower than in the hoeing alone and cutlass weeding treatments. There was significant difference between cutlassing and weedy treatments and also, between hoe weeding and weedy treatment on all sampling occasion.

Table 4.8: Effect of variety and weed management strategies on weed biomass, 2014-2015.

Treatment	**Weed biomass (g)**			
	1 MAP	**2 MAP**	**3 MAP**	**4 MAP**
<u>Variety</u>				
Dokuduade	0.83	1.25	0.66	0.95
Ampong	0.56	0.94	0.43	0.71
LSD (5%)	**0.06**	**0.08**	**0.15**	**0.06**
<u>Weed control treatments</u>				
Hoe-weeding	0.73	0.98	0.23	0.73
Cutlass weeding	0.92	1.40	1.02	1.25
Weed-free	-	-	-	-
Butachlor + 2 hoe-weeding	0.56	1.18	0.08	0.51
Terbulor + 2 hoe-weeding	0.38	0.63	0.05	0.20
Weedy	1.08	1.57	1.85	1.93
LSD (5%)	**0.10**	**0.14**	**0.27**	**0.11**
CV (%)	**15.5**	**13.0**	**48.8**	**27.1**

4.9 Grass Weed Density

Grass weed density was significantly lower under Ampong than Dokuduade variety on all days of sampling (Table 4.9). For the weed control measures, grass weed density in the Terbulor + 2 hoe-weeding treatment was significantly lower on each sampling period than all other treatment effects. Grass weed density in the Terbulor + 2 hoe-weeding treatment was also significantly lower than the Butachlor + 2 hoe-weeding applied treatments. The herbicide applied + 2 hoe-weeding treatments also recorded lower grass weed biomass than the hoeing and cutlass weeding treatments. In addition, there were no significant difference between hoe weeding and Butachlor + 2 hoe-weeding at 1, 2 and 3 months after planting (MAP).

Table 4.9: Effect of variety and weed management strategies on grass weed density, 2014-2015.

Treatment	**Grass weed density/m^2**			
	1 MAP	**2 MAP**	**3 MAP**	**4 MAP**
Variety				
Dokuduade	0.68	0.71	0.65	1.05
Ampong	0.53	0.57	0.45	0.93
LSD (5%)	**0.06**	**0.06**	**0.12**	**0.04**
Weed control treatments				
Hoe-weeding	0.69	0.74	0.53	1.00
Cutlass weeding	0.79	0.85	0.93	1.15
Weed-free	-	-	-	-
Butachlor + 2 hoe-weeding	0.63	0.63	0.36	0.96
Terbulor + 2 hoe-weeding	0.28	0.27	0.03	0.71
Weedy	0.92	0.90	1.33	1.28
LSD (5%)	**0.10**	**0.11**	**0.21**	**0.07**
CV (%)	**17.0**	**17.3**	**38.3**	**7.5**

4.10 Broadleaved Weed Density

Broadleaved weed density was significantly higher (P < 0.05) under Dokuduade than Ampong variety on all sampling days (Table 4.10). For the weed control methods, broadleaved weed density in the Terbulor + 2 hoe-weeding treatment was the lowest at 2 and 3 MAP measurements, which was significantly lower (P < 0.05) than other weed control treatments. Among the physical control methods, the broadleaved weed population in the hoeing treatment was significantly lower than in the cutlass weeding on all days of sampling. Once again, population in the weedy check was significantly higher than in all other treatments.

Table 4.10: Effect of variety and weed management strategies on broadleaved weed density, 2014-2015.

Treatment	**Broadleaved density/m^2**			
	1 MAP	**2 MAP**	**3 MAP**	**4 MAP**
Variety				
Dokuduade	0.88	0.77	0.68	1.32
Ampong	0.76	0.62	0.40	1.17
LSD (5%)	**0.05**	**0.05**	**0.10**	**0.10**
Weed control treatments				
Hoe-weeding	0.83	0.76	0.42	1.31
Cutlass weeding	0.92	0.84	0.82	1.54
Weed-free	-	-	-	-
Butachlor + 2 hoe-weeding	0.78	0.68	0.44	1.13
Terbulor + 2 hoe-weeding	0.55	0.37	0.21	0.83
Weedy	1.13	0.95	1.11	1.63
LSD (5%)	**0.08**	**0.09**	**0.17**	**0.19**
CV (%)	**10.5**	**14.0**	**31.9**	**15.0**

4.11 Sedge Weed Density

Sedge weed density was significantly higher (P < 0.05) under Dokuduade than Ampong variety (Table 4.11). Sedge weed density in the Terbulor +2 hoe-weeding treatment plots were the lowest at all different sampling measurements, and its effects was significantly lower (P < 0.05) than all other weed control methods at 2 and 3 MAP. At 1 and 3 MAP, the two herbicides + 2 hoe-weeding treatment effects were similar, but either effect was significantly lower than hoeing and cutlass treatment effects. The hoeing treatment effect was significantly lower than the cutlass control method on all days of measurements. In addition, there was no significant difference between cutlass weeding and weedy treatment at 4 months after planting. Lastly, the weedy check effect was greater than all other treatment effects on all days of sampling.

Table 4.11: Effect of variety and weed management strategies on sedge weed density, 2014-2015.

Treatment	**Sedge weed density/m^2**			
	1 MAP	**2 MAP**	**3 MAP**	**4 MAP**
<u>Variety</u>				
Dokuduade	0.44	0.53	0.56	0.82
Ampong	0.27	0.37	0.34	0.58
LSD (5%)	**0.09**	**0.07**	**0.10**	**0.10**
<u>Weed control treatments</u>				
Hoe-weeding	0.40	0.54	0.42	0.84
Cutlass weeding	0.57	0.77	0.89	1.04
Weed-free	-	-	-	-
Butachlor + 2 hoe-weeding	0.15	0.32	0.16	0.61
Terbulor + 2 hoe-weeding	0.11	0.07	0.09	0.36
Weedy	0.86	0.96	1.15	1.18
LSD (5%)	**0.16**	**0.12**	**0.17**	**0.18**
CV (%)	**45.3**	**27.0**	**38.7**	**26.4**

4.12 Weed Species

The different weed species found in the experimental area before land preparation were: *Panicum maximum, Cynodon dactylon, Imperata cylindrica, Brachiaria deflexa* and *Rottboellia cochinchinensis* (grasses); *Mimosa pudica, Centrosema pubescens, Euphorbia heterophylla, Croton hirtus, Tridax procumbens,* and *Euphorbia hirta* (Broadleaved weeds); *Cyperus rotundus* (Sedges).

A total of 23 weed species belonging to 11 families were found in the experimental plots different sampling periods. The weed species consisted of 5 Asteraceae, 4 Euphorbiaceae, 5 Poaceae, and 2 Fabaceae. The remaining families: Commelinaceae, Convolvulaceae, Cyperaceae, Loganiaceae, Malvaceae, Molluginaceae, and Rubiaceae had one each (Table 4.12). The most abundant weed species found during weed assessment were *Tridax procumbens, Panicum maximum, Mimosa pudica, Euphorbia heterophylla, Croton hirtus, Spigelia anthelmia, Digitaria ciliaris, Centrosema probescens* and *Brachiaria deflexa*. Those with moderate abundance *were Ageratum conyzoides, Bidens pilosa*, *Commelina benghalensis*, *Phylanthus amarus*, *Cyperus rotundus* and *Eleusine indica*. Broadleaved were the predominant weeds, while sedges were very small in the experimental plots.

Table 4.12: Weed species composition of the experimental plots, 2014-2015.

Family	Weed species	Life cycle	Morphological group
Asteraceae	*Chromolaena odorata*	Perennial	Broadleaf
	Tridax procumbens	Annual	Broadleaf
	Acanthospermum hispidum	Annual	Broadleaf
	Ageratum conyzoides	Annual	Broadleaf
	Bidens pilosa	Annual	Broadleaf
Commelinaceae	*Commelina benghalensis*	Annual/Perennial	Broadleaf
Convolvulaceae	*Ipomoea spp*	Annual/ Perennial	Broadleaf
Cyperaceae	*Cyperus rotundus*	Perennial	Sedge
Euphorbiaceae	*Euphorbia heterophylla*	Annual	Broadleaf
	Euphorbia hirta	Annual	Broadleaf
	Phyllantus amarus	Annual	Broadleaf
	Croton hirtus	Annual	Broadleaf
Loganiaceae	*Spigelia anthelmia*	Annual	Broadleaf
Malvaceae	*Sida acuta*	Perennial	Broadleaf
Poaceae	*Brachiaria deflexa*	Annual	Grass
	Eleusine indica Gaertn	Annual	Grass
	Rottboellia cochinchinensis	Annual	Grass
	Digitaria ciliaris	Annual	Grass
	Panicum maximum	Annual	Grass
Fabaceae	*Mimosa pudica*	Annual/ Perennial	Broadleaf
	Centrosema pubescens	Perennial	Broadleaf
Molluginaceae	*Mollugo sp*	Annual	Broadleaf
Rubiaceae	Borreria sp	Annual or perennial	Broadleaf

4.13 Yield and Yield Components of Cassava

The root yield, root number, dry matter content and harvest index of Ampong variety was significantly higher ($P < 0.05$) than Dokuduade (Table 4.13). The results also showed that number of roots and dry matter content of Terbulor + 2 hoe-weedings was significantly higher ($P < 0.05$) than all other treatments. Treatment effects of hoe weeding and cutlass weeding were not significantly different for total root number per plot, while hoe weeding alone and weed-free treatments were significant. Treatment effect of the weedy check for both parameters were significantly lower than all other treat effects.

Fresh root yield for Ampong variety was 57% greater than in Dokuduade, although their harvest indices were similar. Between the chemical controls, root yield under Terbulor + 2 how-weedings was 27% greater than that under Butachlor + 2 hoe-weedings. The herbicide controls had root yields averaging 67% greater than the two physical controls of hoeing and cutlassing. Weed-free treatment had root yield about 3.7 times greater than the weedy treatment.

Harvest index was greatest in the Terbulor + 2 hoe-weeding treatment and this was significantly higher than other treatment effects, except the weed-free and Butachlor + 2 hoe-weeding treatments.

Table 4.13: Effect of variety and weed management strategies on total root number, fresh root yield, dry matter percentage and harvest index of cassava at 12 MAP.

Treatment	Total root number per plot	Fresh root yield (t/ha)	Dry matter %	Harvest index %
Variety				
Dokuduade	48.71	14.92	0.43	0.22
Ampong	58.42	23.41	0.50	0.23
LSD (5%)	**2.35**	**2.69**	**0.01**	**0.01**
Weed control treatments				
Hoe-weeding	52.25	18.12	0.46	0.23
Cutlass weeding	50.38	12.44	0.45	0.19
Weed-free	58.38	26.16	0.49	0.25
Butachlor + 2 Hoe-weeding	55.38	22.50	0.47	0.24
Terbulor + 2 Hoe-weeding	63.25	28.59	0.53	0.27
Weedy	41.75	7.16	0.39	0.18
LSD (5%)	**4.07**	**4.65**	**0.02**	**0.03**
CV	**7.5**	**23.9**	**4.9**	**14.7**

4.14. Sensory Evaluation of Cooking Quality Cassava Varieties

Table 4.14a showed sensory evaluation of Dokuduade variety cooking quality for poundability, elasticity, lumpiness and mealiness. All other weed control methods scored 100% of poundability with the exception of weed-free treated plots which was 80%. Also, hoe, cutlass, weed-free and weedy treated plots scored 100% of elasticity, while both pre-emergence herbicides aided with two hoe-weedings scored 90%. Terbulor + 2 hoe-weeding recorded the highest percentage (90%) for lumpiness. Butachlor + 2 hoe-weeded plots scored higher percentage (100%) of non-mealiness compared to those other weed control treatments and not suitable for fufu Preparation.

Table 4.14a: Effect of weed management strategies on cooking quality of Dokuduade variety at 12 MAP.

Cooking quality	Hoe weeding		Cutlass weeding		Weed-free		Butachlor + 2 hoe-weeding		Terbulor +2 hoe-weeding		Weedy	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Poundability												
Poundable	10	100	10	100	8	80	10	100	10	100	10	100
Non-poundable	0	0	0	0	2	20	0	0	0	0	0	0
Elasticity												
Elastic	10	100	10	100	10	100	9	90	9	90	10	100
Inelastic	0	0	0	0	0	0	1	10	1	10	0	0
Lumpiness												
Lumpy	6	60	0	0	8	80	8	80	9	90	4	40
Non-lumpy	4	40	10	100	2	20	2	20	1	10	6	60
Mealiness												
Mealy	7	70	10	100	2	20	0	0	1	10	1	10
Non-mealy	3	30	0	0	8	80	10	100	9	90	9	90

Sensory evaluation of Ampong variety cooking quality for poundability, elasticity, lumpiness and mealiness are shown in Table 4.14b. All other weed control methods scored high percentage of poundability (100%) with the exception of Butachlor treatment scored (90%). Elasticity was 100% for the various weed control measures, while hoe, cutlass and weedy treated plots scored 100% of non-lumpiness and Butachlor treatment scored the lowest of 50% respectively. All other weed control methods scored high percentage of mealiness with the exception of Butachlor treatment which scored the lowest of 30% and not suitable for fufu preparation.

Table 4.14b: Effect of weed management strategies on cooking quality of Dokuduade variety at 12 MAP

Cooking quality	Hoe weeding		Cutlass weeding		Weed-free		Butachlor +2 hoe-weeding		Terbulor + 2 hoe-weeding		Weedy	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Poundability												
Poundable	10	100	10	100	10	100	9	90	10	100	10	100
Non-poundable	0	0	0	0	0	0	1	10	0	0	0	0
Elasticity												
Elastic	10	100	10	100	10	100	10	100	10	100	10	100
Inelastic	0	0	0	0	0	0	0	0	0	0	0	0
Lumpiness												
Lumpy	0	0	0	0	1	10	5	50	2	20	0	0
Non-lumpy	10	100	10	100	9	90	5	50	8	80	10	100
Mealiness												
Mealy	10	100	9	90	10	100	3	30	10	100	10	100
Non-mealy	0	0	1	10	0	0	7	70	0	0	0	0

4.15 Partial Budget Analysis for Cassava Production

Table 4.15 showed the streams of total cost of production (TCP), gross revenue (GR) and net revenue (NR) per hectare under various weed management strategies. The budget analysis showed Terbulor + 2 hoe-weeding had maximum gross revenue (7176.09 GH¢/ha) and net revenue or profit (6899.18 GH¢/ha) per hectare than other weed control methods. This result implies that Terbulor + 2 hoe-weeding was economically a better weed control measure than other weed control methods evaluated in this study. Also weed-free treated plots had higher gross revenue (6566.16 GH¢/ha) and net revenue or profit (5735.97 GH¢/ha) than Butachlor + 2 hoe-weeding and 3 hoe-weeding treatments. Weedy treated plots had significantly lower gross revenue (2015.53 GH¢/ha) and net revenue or profit (1807.85 GH¢/ha) than all other weed control methods. Weed-free treatment had the highest total cost of production (830.74 GH¢/ha) than the various weed management strategies.

The marginal rate of return (MRR) for applying 3 Cutlass weeding over weedy plot = 279.8%. This means for any extra cost of GH¢ 100.00/ha incurred for adding 3 Cutlass weedings over the weedy treatment, the farmer will recoup the GH¢ 100.00 and make an extra income of GH¢ 179.8/ha. The Butachlor + 2 hoe-weedings has dominated the 3 Hoe weedings because the 3 Hoe weeding has less net revenue (NR) but higher total cost of production than adopting the Butachlor + 2 Hoe weeding. In addition, Terbulor + 2 Hoe weedings has dominated the weed-free treatment because the weed-free has less net revenue (NR) but higher total cost of production (TCP) than adopting the Terbulor + 2 Hoe weeding.

Table 4.15: Partial budget analysis of cassava production under different weed management strategies, 2014-2015.

Treatment	Fresh root Yield t/ha	Gross revenue GH¢/ha	Total cost of production GH¢/ha	Net revenue GH¢/ha	Marginal rate of return
Weedy	8.03	2,015.53	207.68	1,807.85	-
Cutlass weeding	12.22	3,067.22	484.60	2,582.62	279.78
Hoe-weeding	18.12	4,548.12	553.82	3,994.30	2,039.41
Butachlor + 2 hoe-weeeding	22.50	5,647.5	311.53	5,335.97	-553.75
Weed-free	26.16	6,566.16	830.74	5,735.97	77.04
Terbulor + 2 hoe-weeding	28.59	7,176.09	276.91	6,899.18	-210.04

*Selling price of cassava was GH¢ 251 per ton

CHAPTER FIVE

5.0 DISCUSSION

5.1. Effectiveness of various weed control measures

The eminent weeds identified in the experimental plot contained all classes of weeds i.e. broad leaf, grasses and sedges (Table 4.12). A total of 23 different weed species belonging to 11 families were identified in this study. Broadleaved weeds were predominant over grasses and sedges. This result agrees with the report of various weed flora found in the same area by Sattin and Berti (2006).

Significantly, lower weed density was observed in hoe weeded plots than cutlass weeding treatment (Table 4.7). This could be attributed to the fact that hoeing removed the roots of weeds, which reduced sprouting. The tendency of weeds to sprout under cutlass weed control method is high due to rapid growth of nodes on stems partly cut-off. This result similarly agrees with the report of Chikoye *et al*. (2005) who reported a 33% increase in maize yield in hoe-weeded plots due to low weed density. Weed-free treatment resulted in effective weed control, but Terbulor + 2 hoe-weeding was found to be economical (Table 4.15) with less weed infestation (Table 4.7) and maximum root tuber yield (Table 4.13) as compared to Butachlor supplemented with two hoe-weeding and manual physical weeding methods. Plots subjected to pre-emergence herbicides application of Terbulor and Butachlor supplemented with two hoe-weeding significantly recorded lower weed density, which attests the effectiveness of the herbicides than cutlass and hoe-weeding treatments. Similarly, Adigun and Lagoke (2003) reported that herbicides have not been consistent in giving season –long weed control and often requires supplementary hand weeding. This result also agrees with the report of Silva *et al.*

(2012) that chemical control appears to be an extremely good alternative for weed control in cassava.

Similar trend was observed in the control of grasses, broadleaved weeds and sedges (Tables 4.9-4.11). Plots subjected to Terbulor + 2 hoe-weeding obtained lower weed density of grasses, broadleaved and sedges followed by Butachlor aided with two hoe-weeding than other weed control methods. Cutlass weeding had lower grasses, broadleaved and sedge weed densities than weedy treatment which incurred the highest weed density. In general, weed-free method enhanced weed control efficacy throughout the different measurement periods than the two weedicides supplemented with hoe-weeding.

Weed biomass was also affected by various weed management strategies, such that weed biomass under the weed-free treatment was absolutely nil due to frequent weeding regime than other weed control methods. In addition, weed biomass under hoe weeding was lower than cutlassing. Chikoye *et al*. (2005) similarly reported on lower weed dry matter in hoe weeded plots than cutlass treatment. Plots treated with Terbulor and Butachlor + two supplementary hoe-weeding showed visible effect at 3 MAP and produced lower weed biomass (0.05 and 0.08g/m^2) respectively. This was due to the fact that the herbicides were more toxic to weeds, thus enhanced weed control efficacy. Weed biomass under weedy control treatment obtained the highest gross weed biomass.

5.2. Weed control on cassava growth and yield

Cassava stand establishment percentage was significantly higher with weed-free (37.86%) followed by Terbulor + 2 hoe-weeding (28.93%) treatment than the other weed control methods (Table 4.1). Weedy control had the lowest stand establishment (1.43%). The lower percentages of cassava establishment in this study was attributed to lack of rainfall immediately after planting and termites attack. The wider canopy spread observed in Ampong could be attributed to the genetic makeup of the variety, thus its effect under weed-free treatment was highly significant than other weed control measures. The pre-emergence herbicides with two supplementary hoe-weeding produced wider canopy spread than hoe-weeding and cutlass weeding. In the case of plant height, branch height, branch number and stem girth, weed-free treatment recorded the highest of these parameters followed by Terbulor + 2 hoe-weeding than other weed control methods applied in this study. These parameters were also the lowest with weedy control treatment than all other control measures. This result agreed with Chikoye *et al*. (2001), who reported crop failure grown in slashed plots and no weeding.

Cassava tuberous root yield was significantly higher with Terbulor + 2 hoe-weeding than other weed control methods in this study due to the efficacy of the herbicide which reduced weed suppression. This agrees with Chikoye (2004) who reported that plots treated with Primextra + 2 hoe-weeding produced significantly higher average maize grain yield. Terbulor + 2 hoe-weeding effectively controlled weeds as reflected in reduced weed density and weed biomass which agrees with the report of Mahadi *et al*. (2007). Terbulor + 2 hoe-weeding treatment showed dominance over other weed control methods especially cutlass weeding treatment which had similar effect as weedy control treatment. Cutlass and weedy control methods were insufficient in eradicating weeds as indicated by increased weed density and weed biomass resulting in reduced root yield. Yield reduction in the weedy check treatment was due to effects of competition for available light, water and nutrients.

5.3. Effect of weed control on tuber cooking quality

The result showed that the application of Terbulor + 2 hoe-weeding produced the highest number of roots, root yield, root dry matter percentage and harvest index percentage followed by weed-free treatment than other weed management strategies. This result conforms to Alabi *et al*., (1999) that good root yield was favoured when atrazine and metolachlor are applied at a rate of 2.0kg a.i/ha. Consequently, weedy treatment had the lowest fresh root number, root yield, dry matter content and harvest index in this study. Ampong variety appeared to be well-adapted to environmental conditions and had preferred root cooking quality. According to Adjei-Nsiah and Issaka (2013), most of the cassava varieties grown on depleted soils likely have poor cooking quality or are not mealy, poundable and consequently cannot be boiled and eaten as "ampesi" or pounded into "fufu" - which are the most common traditional ways of preparing cassava as food in ghana. Plots treated with Butachlor showed higher percentage of lumpiness and non-mealiness on the cooking quality of both varieties. This probably may be attributed to the physiochemical components because when the starch granules of the varieties do not swell to the desired level, it results in non-mealiness and hardness due to the fact that granular structures are not disintegrated to release starch molecules.

5.4. Economics of various weed control measures

The costs and benefit analysis of various weed control methods of cassava production are showed in Table 4.15. The value of gross revenue from various weed control treatments varied from GH¢ 2,015.53 to GH¢ 7,176.09. The greatest revenue was recorded under Terbulor + 2 hoe-weeding (GH¢ 7,176.09) followed by weed-free (GH¢ 6,566.16), while cutlass weeding and weedy treatment (GH¢ 3,067.22) and (GH¢ 2,015.53) respectively had the least revenue among the weed management strategies evaluated. These results were due to differences in yield/ha recorded by the various weed control methods with Terbulor + 2 hoe-weeding resulting in the highest yield.

Weed-free treatment incurred the highest cost of production (GH¢ 830.74) followed by three-manual hoe-weeding (GH¢ 553.82), while Terbulor + 2 hoe-weeding and weedy treatment recorded the lowest cost of production (GH¢ 276.91) and (GH¢ 207.68) respectively compared to other weed control methods. This result is similar to Adigun and Lagoke (2003) who reported that hoe-weeding is expensive. Also, Chikoye *et al*. (2002) similarly showed that chemical weed control in cassava was cheaper than hoe weeding. It also shows the merit of herbicide application over hoe-weeding in the reduction of cost of production of cassava.

Terbulor + 2 hoe-weeding obtained the highest net profit (GH¢ 6,899.18) followed by weed-free (GH¢ 5,735.97) compared to other weed control methods, while the lowest net profit was obtained under cutlass weeding (GH¢ 2,582.62) and weedy treatment (GH¢ 1,807.85). These results confirms the findings of Chikoye *et al.* (2005), who reported that chemical weed control is a better alternative to manual weeding because it is cheaper, faster and gives better weed control.

The marginal rates of return (MRR) for applying cutlass weeding treatment was significantly greater over weedy treatment, meaning that for any GH¢ 100.00/ha spent for cutlass weeding, the farmer will make extra interest of GH¢ 179.8/ha. Similarly, the application of Butachlor and Terbulor with two supplementary hoe-weeding dominated hoe weeding alone and weed-free treatments respectively. This was due to less net revenue and higher total cost of production for applying 3 hoe weeding and weed-free (weeding at two weekly interval until harvest) treatments.

5.5 Performances of cassava morphotypes on weed control

In this study, Ampong variety (Early branching) produced wider canopy spread, larger branch number and higher root yield than Dokuduade, which could be attributed to structural morphological growth differences, which influences light transmission to the ground, and so, the efficacy of weed control and management. Similarly, there was a reduction in weed dry matter and weed density in plots planted to the early branching cassava variety in comparison to the late branching. These decrease in weed dry matter and density with the early branching variety was attributed to shading occasioned by the lesser quantity and quality of light reaching the soil surface, which negatively influenced weed growth. This result agrees with Teasdale and Daughty (1993), who reported that high vegetative biomass of early branching crop is a good potential for physical obstruction of light and weed seedling emergence. Generally, late branching variety obtained taller plants, suggesting differential varietal growth potential.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The results indicated variable effectiveness of the various weed control measures studied. Among these, the Terbulor + 2 hoe-weeding treatment was most effective in the control of early weed growth. The results also showed that the application of two pre-emergence herbicides supplemented with two hoe-weeding resulted in better weed control than in the physical traditional methods and resulted in tuberous root yields and net revenues comparable to or better than those other control measures. Additionally, while the application of Terbulor did not have any effect on the quality of tuberous roots of both varieties, the Butachlor herbicide affected negatively the mealiness of the root, which resulted in high lumpiness. The results also indicated that treatments that offered better weed control promoted better growth and yield. In addition, the structural morphological growth of Ampong variety had significant effect on weed control and management. Finally, the cost of using the Terbulor + 2 hoe-weeding was lower than the rest, while weed-free weeding was the most expensive method of control.

6.2 RECOMMENDATIONS

- Based on the findings in this study, it is recommended that Terbulor with two supplementary hoe-weeding is an effective and economic weed management strategy which can be adopted by farmers.
- In view of the above, cassava farmers must be educated on the potentials of using herbicide to control weeds.

- It is also recommended that farmers should plant cassava varieties that branch early for maximum yield and better weed suppression.
- It is recommended that future or further studies on effects of herbicide on tuberous roots cooking quality be investigated.

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APPENDICES

APENDIX 1

WEATHER DATA

Weather conditions during the establishment of the trial May, 2014 to May, 2015

Month	Temperature (^{0}C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
May	32.1	22.7	73	103.4
June	30.9	22.5	75.5	270
July	28.7	21.5	79.5	91.4
August	27.7	20.9	85	74.2
September	29.3	21.3	83	162.9
October	30.3	21.7	75	138.2
November	32.1	22.4	72	107
December	32.1	21.8	64.5	10.8
January	33.4	17.8	47	2.4
February	33.4	22.2	67.5	53.7
March	33.5	22.2	68.5	108.5
April	33.3	22.8	688.5	183.3
May	32.7	22.9	71	144.6

Source: Agro-meteorology division, Animal Department Kwame Nkrumah University of Science and Technology.

APPENDIX 2

SOIL DATA

SOIL CHEMICAL CHARACTERISTICS DATA 0-30 CM

Sample ID (cm)	% Organic carbon	% Organic matter	% Total nitrogen	K (cmol/kg)	Available P (mg/kg)	pH
A 0-15	1.08	1.86	0.07	0.12	12.13	6.7
A 15-30	0.66	1.14	0.05	0.1	2.7	6.17
B 0-15	1.52	2.62	0.1	0.1	2.7	6.08
B 15-30	0.97	1.67	0.08	0.08	2.7	6.02

Source: Soil analytical laboratory, Crop and Soil Sciences Department, Kwame Nkrumah University of Science and Technology.