MAKERERE UNIVERSITY

COLLEGE OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES

SCHOOL OF AGRICULTURAL SCIENCES

THE DISTRIBUTION AND ABUNDANCE OF BONDAR'S NESTING WHITEFLY (*Paraleyrodes bondari*) ON CASSAVA IN BUSUKUMA SUB COUNTY, WAKISO DISTRICT, UGANDA.

BY

ISABIRYE ZEDEKIA

16/U/19422/PS

ACADEMIC SUPERVISOR: PROF J. KARUNGI

BACHELOR OF SCIENCE IN AGRICULTURE

A SPECIAL PROJECT REPORT SUBMITTED TO THE SCHOOL OF AGRICULTURAL SCIENCES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF SCIENCE IN AGRICULTURE DEGREE OF MAKERERE UNIVERSITY.

FEBRUARY, 2021

DECLARATION

I, Isabirye Zedekia declare that this submission is my original work and contains no material previously published or submitted by any other person to any institution of higher learning for the award of a diploma, degree or any other academic qualification, except where due acknowledgement has been made in the text. I hereby present it in the partial fulfillment of the requirements for the degree of Bachelor of Science in agriculture in Makerere University.

Signature ....

ISABIRYE ZEDEKIA

Date......03rd/3/2021......

This special project report has been submitted to Makerere University, College of Agricultural and Environmental Sciences, School of Agricultural Sciences, with my approval as the academic supervisor.

Signature ....

Associate professor. JENINAH KARUNGI

Lecturer/entomologist, School of Agricultural Sciences

Makerere University

Date......8/3/2021......

DEDICATION

I dedicate this report to Dr. Isabirye Brian and Mrs. Isabirye Catherine for their never ending support in every part of my life, my field and academic supervisors for their endless effort in my academic journey. To all my classmates of Bsc of agriculture and friends who have always encouraged me. May God bless you.

ACKNOWLEDGEMENT

I thank the almighty God for enabling me come this far with my education, for his protection, love, knowledge and always leading me through the right path. I can never thank him enough for always being here with me even in the sad and difficult times.

Great appreciation to all my family members, to my classmates and friends for their heartening efforts towards the completion of my bachelor’s degree. May God always be with you as you all journey in this life and by his guidance and uphold you.

I would like to send my sincere gratitude to my academic supervisor Dr. Christopher Omongo and Associate professor for guidance, support and encouragement as I carried out my research study.

Lastly, I would like to show appreciation to all my lecturers for the entire Degree program and NaCRRI team for providing me with an opportunity to do research with them. I may never thank you enough but all I can say is, God be with you always.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

%	percent
ANOVA	Analysis of variance
B. tabaci	*Bemisia tabaci*
CIAT	International Center for Tropical Agriculture
CMD	Cassava mosaic disease
FAO	Food and agricultural organization
FY	Financial year
GPS	Geographical positioning satellite
H/Q	Head quarters
Ha	Hectare
HSD	Honestly significant difference
IITA	International institute of tropical agriculture
LG	Local government
M	metres
M^2	Square metres
Mt	Metric tons
NaCRRI	National crop resources research institute
ºC	Degrees Celsius
P. bondari	*Paraleyrodes bondari*
STAT	Statistics
UBOS	Uganda Bureau of Statistics
W/F	Whitefly

CHAPTER ONE

INTRODUCTION

1.1 Background

Cassava or manioc (*Manihot esculenta*), is a perennial shrub, one to five metres in height, with palmate leaves bearing three to nine lobes and covered with a shiny, waxy epidermis (Alves, 2002). Cassava is the sixth world food staple after Wheat, rice, maize, potato and barley, and it feeds more than 800 million people in the developing countries (Otekunrin *et al*., 2019). It is highly cultivated by resource limited small holder farmers for its starchy roots (Hillocks, 2002; El-Sharkawy, 2003). Cassava is used as human food either fresh when low in cyanogens, or in many processed forms and products (El-Sharkawy, 2003), mostly starch, flour, biofuel, liquor, making tablets, making confectioneries and biscuits, for animal feeds and many more (El-Sharkawy, 2003). Millions of tons of cassava leaves are also harvested and used as vegetable, which provides protein, vitamins and minerals in Africa (Nweke *et al*., 2001; Hillocks, 2002). Cassava gives a carbohydrate production which is 40% higher than maize. It is the cheapest source of calories providing 1000 calories a day in sub-Saharan Africa (CIAT publication No 341, 2005).

Cassava ranks second to maize as the most widely grown staple crop in Africa (Nweke *et a*l., 2001), Cassava is also ranked second to bananas in Uganda in terms total area per capita (IAEA VIENNA, 2018). Nigeria is the current world's largest producer of cassava with an estimated 54.83 million metric tons per year, while Uganda is the seventh largest producer in Africa producing about 2.81 million metric tons (IAEA VIENNA, 2018) as shown in the table 1 below.

Table 1: Cassava area, production and yield in selected countries of Africa, Asia and Brazil (2014)

Country	Area(mha)	Production(mt)	Yield(tha^{-1})
World	24.22	270.29	11.16
Africa	17.52	146.82	8.38
Nigeria	7.10	54.83	7.72
DRCongo	2.06	16.61	8.08
Ghana	0.89	16.52	18.59
Angola	0.76	7.64	10.10
Mozambique	0.87	5.11	5.88
Tanzania	0.80	4.23	5.28
Uganda	0.85	2.81	3.30
Malawi	0.21	4.91	23.36
Asia	4.13	90.37	21.86
Thailand	1.35	30.02	22.26
Indonesia	1.00	23.44	23.36
VietNam	0.55	10.21	18.47
Cambodia	0.36	8.83	24.57
India	0.23	8.14	35.65
China	0.29	4.68	16.27
Brazil	1.57	23.24	14.83

Source: IAEA VIENNA, 2018

Cassava is adapted to diverse African farming systems and can grow on a wide range of soils (Nweke *et al*., 2001). It is drought tolerant, which attribute makes it the most suitable food crop during periods of drought and famine (Nweke *et al*., 2001). Although the African continent contains most (66%) of the global cassava growing area, cassava productivity in Africa (8.8 t/ha) is much lower than the world average (10.95 t/ha) and the average in Asia (16.8 t/ha) (Kalyebi *et al*., 2018). One reason for the low productivity of cassava in Africa is that it is attacked by numerous insect pests and diseases (Kalyebi *et al*., 2018). The major pests of cassava are cassava green mite (*Mononychellus tanajoa*), cassava whitefly (*Bemisia tabaci*), cassava mealybug (*Phenacoccus manihoti*) (Legg *et al*, 2011).

The most important diseases affecting cassava in Africa include Anthracnose, root rot, brown leaf spot, bacterial blight, angular leaf spot, cassava brown streak virus disease and cassava mosaic disease (Hillocks, Wydra, 2002). The devasting diseases are particularly viral diseases which are cassava mosaic virus disease (CMD) caused by Gemini viruses (Maruthi *et al*, 2014), and cassava brown streak virus disease (CBSD) caused by cassava brown streak viruses which belong to the genus Ipomovirus (Maruthi *et al*, 2014). Both diseases are either transmitted by whiteflies (*Bemisia tabaci*) (Hemiptera: Aleyrodidae) (Omongo, 2003; Mugerwa *et al*., 2018) or spread through vegetative propagation of infected cuttings (Bock & woods 1983). To date, there have been limited practical solutions to combat this increasing problem of whiteflies, due to the inability of subsistence farmers that grow cassava to afford expensive inputs such as insecticide (Omongo *et al*, 2012). The role of cassava whitefly as a vector of cassava mosaic and cassava brown streak viruses cannot be underestimated since CMD is reported to reduce cassava yield by up to 40% and at times 100%, which is equivalent to $1200-2300 million at a conservative value of $100 per ton (Thresh *et al*., 1996; Fargatte *et al*., 2008), while CBSD can cause yield losses of up to 70% and sometimes 100% (Hillocks *et al*., 2001; Kaweesi *et al*., 2014). Efforts have been made by researchers to come up with cassava varieties which are resistant to both diseases, which have led to a level of success in the new varieties, bred especially for CMD but a challenge still exists for CBSD since resistant varieties against this disease have not yet been bred. This poses a great challenge to the cassava production sector in Uganda.

Apart from the *Bemisia tabaci, which* is a major threat to cassava production in Uganda due to its pest status and as a vector, the damage caused by *B. tabaci* include mottled chlorosis on upper leaves, leaf deformation, sooty mold on lower leaves and general plant stunting (Legg *et al* 2004). There has been reports of new species of whitefly which include, *Paraleyrodes bondari* (Bondar's nesting whitefly). This has been observed colonizing cassava fields within the National Crops Resources Research Institute in Wakiso district, central Uganda (Omongo *et al*, 2018). The new whitefly has been reported in other countries like Colombia, United States of America (Dickey *et al,* 2015, Caldwell, 2012) and India (Sundararaji *et al*., 2019) all on different host plants. This pest has characteristic conspicuous grey bands on the wings of the adults and prolific white wax covering its immature instars (Stocks, 2012). Cassava infested by *P. bondari* exhibits severe feeding damage such as wilting and leaf-falling as well as heavy colonization by sooty molds on the lower surface of the leaves (Omongo *et al*, 2018). This leads to a reduction in the photosynthetic area hence leading loss in the crop yield (Omongo *et al*, 2018). Due to its new reported invasion on cassava in Uganda and thus limited information on its distribution, research has been proposed to find out it's distribution and abundance within Busukuma subcounty, Wakiso district, Uganda.

1.2 Problem statement

Whiteflies are key pests in cassava production in Uganda despite efforts to control them. Yield losses of more than 50%, for instance, have been recorded in the worst affected cassava varieties (Legg *et al*., 2004; Omongo *et al*., 2004). The inadequate performance of control efforts in Uganda is partly attributed to a limited understanding of whitefly ecology. For instance, the diversity of whiteflies in Uganda and how this is shaped by host and variety variability, geographical spread and environmental variability is unknown. The cassava whitefly (*Paraleyrodes bondari*) is a new invasive whitefly species in Uganda, which has been found colonizing cassava fields (Omongo *et al*.,2018).*P. bondari* whitefly has been known in other countries to colonize a variety of plants, it has been reported to infest Ficus species, Hibiscus, Sugar apple, Guava, citrus, and many others (Caldwell, 2012; Dickey *et al*., 2015). *P. bondari* has been reported to exist in other parts of the world, colonizing different hosts (Laccarino *et al*., 2011; Castiblanco *et al*., 2016; Mohan *et al*., 2019).

The *Paraleyrodes bondari* cause heavy colonization on the leaves by sooty mold due to the extensive production of honeydew, a sugar like substrate that promotes sooty mold growth on the upper and lower surfaces of leaves. Sooty mold can greatly reduce photosynthesis and overall aesthetic value of hedges and other ornamentals in the landscape, direct feeding by dense whitefly infestations may eventually kill the plant, this leads a reduction in the crop yield. Since Omongo *et al*., (2018) reported the occurrence of *P. bondari* at the research institute, no further efforts have been taken to study the distribution of the pest in surrounding communities. Since this is a fairly new whitefly species in the country, this study will provide lacking information concerning the most vulnerable varieties, crop age, cropping system, and how widely the whitefly is spread in the area, the most affected areas in the Sub County.

1.3 General objective

To contribute towards sustainable management of *Paraleyrodes bondari* in Uganda through understanding its abundance and distribution in Busukuma Sub County, Wakiso district, Uganda.

1.4 Specific objective of the study

1. To determine the occurrence of *Paraleyrodes bondari* among the different parishes, cassava varieties, cropping systems; and role of nearby cassava fields in Busukuma Sub County, Wakiso district, Uganda.
2. To determine the occurrence of *P. bondari* with crop age, *B. tabaci* abundance and cassava mosaic disease severity.

1.5 Hypotheses

1. There is no significant difference in the population of *P. bondari* among the different cassava varieties and variety mixes in different Parishes.
2. Intercropping and proximity to other cassava fields do not significantly affect the population of *P. bondari* among cassava fields.
3. There is no significant relationship between crop age, *B. tabaci*, CMD severity and the population of *P. bondari*.

1.6 Justification of the study

Uganda, like any other developing country is looking forward to expanding her economy through increased production of agricultural crops, but this encounters a number of challenges to achieving this goal. Among these challenges are the pests and diseases and for the case of cassava, whiteflies standout as the pest of major economic importance. This study will provide empirical information about the abundance and spread of the new whitefly species (*Paraleyrodes bondari*) in the different farmer's cassava fields in Busukuma Sub County. The information generated will be vital in the sustainable management of this pest across the whole country and thus guarantee increased cassava yield, consequently boosting both income and food security for the smallholder farmers.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin of Cassava

All 98 species of the Manihot genus, family Euphorbiaceae and sub family Crotonoidae are native to the Neotropics, from where cassava was introduced to other regions of the world (Rogers and Appan, 1973). The cultivated cassava is believed to have originated in South America (Olsen and Schaal, 2001; Allem, 2002). According to Liu *et al*., (2014), cassava production may be said to have originated from the North eastern part of Brazil/ Paraguay to Mexico/ Guatemala in more than 4000 years ago. Cassava belongs to the Euphorbiaceae family, which is made up of about 7200 species, characterized for their notable development of lactiferous vessels, themselves made up of secretory cells called lacticifers. These produce the milky secretion, or “latex”, that characterizes the plants of this family. Plant architecture varies enormously within this family, ranging from arboreal types such as rubber (*Hevea brasiliensis*) to shrubs, also of economic importance, such as the castor-oil plant (*Ricinus communis*). Also representing this family are numerous weeds, ornamental plants, and medicinal plants. A highly significant genus of this family is Manihot to which cassava belongs. Although all species of the genus can cross with each other, evidence suggests that, in nature, they are reproductively isolated.

Of the 98 species described in the genus Manihot, it is only cassava (*Manihot esculenta*) which has economic importance and is cultivated. Perhaps more than 100 common names now exist for this species, owing to its spread throughout the tropical world by early traders. In Latin America, it is usually known either as yuca (Spanish) or as mandioca (Portuguese). In Brazil, sweet cassava (aipim) is distinguished from bitter cassava (mandioca). Other names in different languages include manioc, manioca, tapioca, and mhogo (Cock, *et al*., 1979). Portuguese traders introduced cassava into Africa from Brazil in the sixteenth century. A native of South America and Southern andWestern Mexico, cassava was one of the first crops to be domesticated. There is archeological evidence that it was grown in Peru four thousand years ago and in Mexico some two thousand years ago (Okigbo, 1980). From Mid- and South America, cassava spread to the West Coast of Africa and the Congo in the late sixteenth century, probably in slave ships. The technique of making *gari* from cassava roots was introduced in Sao Tome about 1780, a discovery that aided in the diffusion of cassava in

West Africa. Cassava was introduced into East Africa (Madagascar and Zanzibar) via Reuruon by the end of the eighteenth century. It was widely grown in Africa and Southeast Asia by the 1850s (Okigbo 1980).

Importance and production of cassava

Global production of cassava amounted to about 278 million metric tons in 2018 out of which Africa's share was put at about 61% (FAOSTAT, 2020). It is the third most important source of calories in the tropics after rice and maize (Fauquet and Tohme, 2008). The crop is crucial for both food security and income generation. In Asia and Latin America, cassava serves as livestock feed, an industrial raw material, and a source of food (Ceballos *et al*., 2012). Fauquet and Tohme (2008) described it as the second most important source of calories, an inexpensive food, and emerging cash crop. Cassava is known to have the highest carbohydrates contents among the staple crops (Coursey, 1973). In sub-Saharan Africa, cassava is mainly a subsistence crop grown by small-scale farmers and it feeds over 200 million people daily (FAO, 2013).

World production of cassava root was estimated to be 184 million in 2002, rising to 230 million tons in 2008 (FAOSTAT, 2011) The majority of production in 2002 was in Africa, where 99.1 million tons were grown; 51.5 million tons in Asia and 33.2 million tons in Latin America and the Caribbean, however based on the statistics from the FAO of the United Nations. Thailand is the largest exporting country of dried cassava, with a total of 77% of world export in 2005 followed by Vietnam, with 13.6%, Indonesia (5.8%) and Costa Rica (2.1%). Worldwide cassava production increased by 12.5% between 1988 and 1990, in 2010, the average yield of cassava crops worldwide was 12.5 tons per hectare. The most productive 14 cassava farms in the world were in India with a nationwide average yield of 34.8 tons per hectare in 2010 (Adams *et al*., 2009). In Africa, Nigeria and DR Congo have the largest production per hectare (59 tons and 32 tons respectively). Nigeria, Congo, DR and Uganda have the largest percentage area harvested in hectares (25.79%, 14.72% and 4.51%) (Otekunrin and Sawicka, 2019).

Cassava, which can grow well on marginal lands, is one of the most important staple foods in Uganda. It is estimated that 60% of the production is destined for household consumption and 40% for marketing (Kimathi, *et al, (2007*). According to (Kirya, *et al*, 2012), cassava, which is known as a “poor man’s crop”, is predominantly grown by subsistence farmers as a staple crop on plots averaging 1 to 3 acres. Cassava production statistics are confusing in that there are large discrepancies between different sources of information. According to a speech given by H.E. YK Museveni (June 2012) the annual cassava production in Uganda is 6.7 million tons, compared to over 30 million tons produced annually in East and Central Africa. Cassava is grown by 29 percent of agricultural households. In 2018, about 4.4 million tonnes were produced from land area of about 941,000Ha. The annual yield of cassava was 8.7MT/Ha (UBOs annual agriculture survey, 2018).

Cassava plays a particularly important role in agriculture in developing countries, especially in sub-Saharan Africa, because it does well on poor soils and with low rainfall, and because it is a perennial that can be harvested as required. Its wide harvesting window allows it to act as a famine reserve and is invaluable in managing labor schedules. It offers flexibility to resource-poor farmers because it serves as either subsistence or a cash crop. (FAOSTAT, 2011: Adjebeng-Danquah *et al*., 2012). Nweke *et al*., (2002) stipulated that the bulk of cassava production is consumed as food. Cassava is described as a ‘classic food security crop’ (DeVries and Toenniessen, 2001).

Constraints to cassava production

Despite cassava’s major contribution to the economy, it faces a myriad of production constraints which include: Shortened fallow periods and declining soil fertility, lack of access to good quality planting materials, lack of well adapted varieties, slow variety improvement and adoption, poor crop production systems (Hillocks, 2002) and plant pests and diseases which include: Cassava green mite (*Mononychellus tanajoa*), Cassava mealybug (*Phenacoccus manihoti*), root mealybug (*Planococcus citri), Prostephanus truncates* andCassava whitefly mostly *Bemisia tabaci* (Hillocks, 2002). The major diseases are Cassava mosaic virus disease, Cassava brown streak virus disease, Cassava bacterial blight (*Xanthomonas axonopodis*), Cassava anthracnose disease (*Colletotrichum gloeospoiodes*) and root rots (Hillocks, 2002). Of the invertebrate pests that attack cassava in East Africa, the whitefly, *Bemisia tabaci* (Hemiptera: Aleyrodidae) is among the most challenging to control (Kalyebi *et al*., 2018). Whiteflies are plant-parasitic insects comprising a single family, the Aleyrodidae, with more than 1,550 described species worldwide (Martin & Mound, 2007). Several species are important economic pests of crops and ornamental plants. They damage plants in three main ways: by feeding on plant sap; by contamination of fruit and foliage with honeydew eliminated by the larvae, which serves as a medium for the growth of black sooty moulds; and by the adults acting as vectors of plant-pathogenic viruses (Mulumphy and Mifsud, 2016). Whiteflies are one of the most frequently transported groups of insects in international plant trade (Malumphy *et al*., 2010) and many species are successful colonisers (Mifsud *et al*., 2010). Incidence of invasive whitefly species (*Paraleyrodes* species) have been reported in different parts of the world (Mulumphy and Mifsud, 2016; Omongo *et al*., 2018; Sujithra *et al*., 2019).

2.2 The cassava whitefly (*Paraleyrodes bondari*)

2.2.1 Taxonomy, diversity and distribution

The cassava whitefly, *Paraleyrodes bondari* is classified from kingdom to genus as follows; Animalia, Arthropoda, Insecta, Hemiptera, Sternorrhnycha, Aleyrodoidea, Aleyrodidae, *Aleurodicine*, *Paraleyrodes* (CABI, 2019). The genus *Paraleyrodes* include: *Paraleyrodes minei* (*P.minei*), *P.bondari*, *P.naranjae*, *P.perplexus*, *P.persea*,*P.proximus*, *P.pseudonaranjae*, *P.pulverans*, *P.singularis*, *P.triangulae* and *P.urichii* (Martin *et al*., 2000; Martin *et al*., 2001; Martin, 2004).

2.2.2 Description of *Paraleyrodes* whitefly

Genus *Paraleyrodes* is physically much smaller than most other *aleurodicines*; puparium with 5 or 6 compound pores,, in which the anterior 1 or 2 pairs much smaller than the remaining 4 abdominal pairs and the cephalic pair; thorax (Martin, 2004). The whitefly has two pairs of cicatrices and a pair of sub median setae: outer sub margin with a row of 14 pairs of hair-like setae as shown in figure one. Adults with all wing veins unbranched; females have four articulated antennal segments; males have only three articulated antennal segments and complex aedeagal apices. The larva and puparia secrete long waxy filaments that often form an annulus surrounding the feeding insects" (Martin, 2004). Adults remain inside a nest like mealy wax and females usually secrete so much wax around them while ovipositing (figure one) and hence the members of this genus are appropriately known as "nesting whiteflies" (Martin, 2004).

Figure 1: *Paraleyrodes* whitefly life cycle stages 1: Puparium. 2: Teneral 4th instar larva. 3: Larva in waxy 'nest'. 4: Adult female and eggs (Mulumphy and Mifsud, 2016).

The puparia of *P. bondari* are characterized by the presence of 14 pairs of submarginal setae and anterior 2 of 6 abdominal compound pores reduced in size and with a rim of chitinous splines. In life, the adult forewings are with two rows of mottelings. The aedeagus of *P. bondari* is unique and easily distinguishable from other *Paraleyrodes* species in having three subapical aedeagal processes of which two are in one direction and one opposite to them, and one process near mid-length of it (Vidya *et al*., 2019). Adults are smaller than other whitefly species, measuring approximately 1 mm long. A pair of greyish brown bands forms an "X" pattern on the forewings. Nymphs produce flocculent wax and long, thin, rod-like filaments. A clear wax band containing a row of short wax filaments resembles a "skirt" around nymphs. Fourth instar nymphs are translucent yellow and surrounded by a "nest" of white wax (Casuso *et al*., 2017).

2.2.3 Biology of *Paraleyrodes* whitefly species

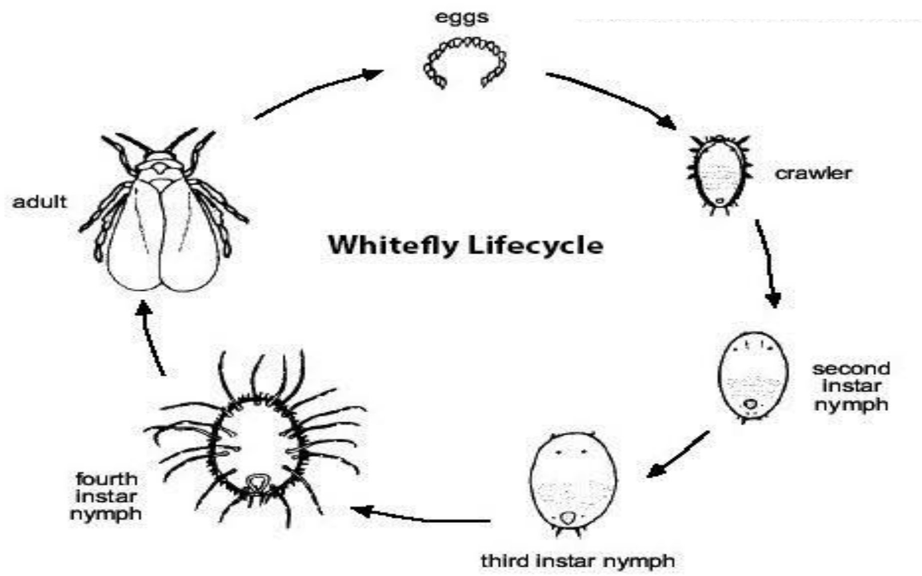

Figure 2: General life cycle of whitefly

Biology revealed four nymphal instars as illustrated in figure 2 above. Eggs are laid in circular “nests” of wooly wax, with number of eggs laid by a female ranging from 36 to 75 (Sujithra *et al*., 2019). Freshly laid eggs are oval, pale yellowish with a long pedicel which turned into dark yellowish or orange before hatching (7.6 ± 0.89 days). Four nymphal instars consisting of crawlers /I nymph instars (3.2 ± 0.83 development days), II and III nymphal instars (7.0 ± 1.73 development days), IV instar were observed with total nymphal development period 4.8 ± 0.83 days. Crawlers are active, mobile, oval and translucent with hyaline fringe of wax filaments along the lateral margin (Sujithra *et al*., 2019). Second and third nymphal instars are immobile and had a pair of yellow spots below the midline of the body. Puparium is elliptical, yellowish to orange and surrounded by filamentous wax stands extending from the dorsum. Adults are pale yellow with mild powdery wax coating on the body and wings flattened dorsally over the body; body length from head to the tip of the abdomen measured 1.106 ± 0.09 mm; and total life cycle ranged from 20- 26 days (Sujithra *et al*., 2019).

According to Otim-Nape *et al*., (1996), the adult whiteflies invade their host slowly establish and thereafter a small population appears after 3 weeks of the initial colonization followed by rapid buildup in 3 to 4 months after planting. This rapid buildup is attributed to the much available young tender foliage on the plant that the whiteflies enjoying feeding on. A steady population growth follows for a short period, followed by a rapid decline, which is maintained throughout the rest of the crop's growth period (Fishpool and Burban, 1994, Fishpool *et al*., 1995). This decline is explained by the reduced food quality caused plant aging. Tuberization is also another factor responsible for decline in whitefly population since the resultant changes in resource partitioning within the plant may adversely affect the nutritional quality of the aerial parts. In other words, food resources are devoted to aerial growth during the early growth period (1 to 3 months) and declines are observed after 4 to 5 months when the process of root tuberization begins. The same authors also clearly stated that the variation in population of whiteflies were attributed to the growth stage of the crop (cassava), variety as well as abiotic factors like rainfall, temperature, wind and relative humidity. Fishpool and Burban (1994) also confirmed in their study that high temperatures and radiation, low rainfall and relative humidity were the main biotic factors responsible for an explosion in the population of whiteflies. The dispersal of whiteflies is by wind that enables them to travel short and long distances as well as movement of the nymphs in the planting materials facilitated by human beings (Byrne and Bellows, 1991). The variation in population of whiteflies was also attributed to the cropping systems, which advocate for mixed cropping and intercropping (Fargette and Fauquet, 1988).

2.2.4 Distribution and hosts of *Paraleyrodes bondari* whitefly

There has been a worldwide distribution of *P.bondari* where it has been reported in countries like Brazil, Honduras, Venezuela, Belize, Puerto rico, Hawaii, Comoros, Mauritius, Taiwan and U.S.A (Dickey *et al*,.2015, Caldwell,2012), has also been reported in Indian mainland, Andama and Nicobar islands (Sundararaji *et al*., 2019) and Uganda (Omongo *et al*., 2018). Hosts include: Coconut, Guava, Citrus, Hibiscus, Sugar apple, Surinam cherry and Ovacado (Dickey *et al*,.2015, Caldwell,2012), *Artocarpus heterophyllus*, *Capsicum annum*, *Bridelia retusa*, *Cinnamomum verum*, *Mangifera indica*, *Leucaena leucocephala*, *Musa spp*, *Tectona grandis* and *Morinda citrifolia* (Sundararaji *et al*., 2019) and *Manihoti esculenta* (Omongo *et al*., 2018).

2.2.5 Damage by *Paraleyrodes bondari* whitefly on crops

Whiteflies, nymphs and adults, feed by inserting their mouth parts into plant phloem and withdrawing sap (Martin *et al*., 2000). To cope with the liquid source of nutrients that the phloem contains, whiteflies have an alimentary filter system in the gut, which allows water and sugars to be absorbed speedily leaving amino acids and other more essential nutrients to be digested (Carver *et al*., 1994). Sufficient protein- building amino acids are extracted from the sap to facilitate body growth. The sugar- rich excreta, termed ‘honeydew,’ may support growth of sooty mold on affected plants (Oliveira *et al*., 2001). The *P. bondari* whiteflies produce extensive honeydew; a sugar rich excretion that promotes sooty mold growth on both the upper and lower surfaces of leaves. The sooty mold can greatly reduce photosynthesis, overall aesthetic value of hedges and other ornamentals in landscape and may increase thermal absorption thereby raising the leaf temperature (Casuso *et al*., 2019). Direct feeding by dense whitefly infestations may cause premature leaf drop and decreased plant vigor, untreated infestations may eventually kill the plant (Casuso *et al*., 2019). The economic importance of whiteflies in agriculture, horticulture and forestry seems to be increasing (Martin and Mound, 2007).

CHAPTER THREE

MATERIALS AND METHODS

3.1 The study area

A biological survey was conducted in Busukuma subcounty, Kyadondo county, Wakiso district, Uganda. The district has a population of 2,007,700 and density of 1,100/km2. The area receives bimodal rainfall with an annual average precipitation of 1320mm as well as temperatures ranging from 18 °C to 26°C and an average humidity of 70%. The rainfall is distributed between two seasons; one lasting from March to June and other from September to November (Wakiso district LG development plan FY 2015/16-2019/20). The area lies at an altitude between 900-1340m above mean sea level (Nsubuga et al, 2011). The soils in this area are medium to high fertility that favors high agricultural activity and are mainly sandy clay loams. The minimum surface air temperature of the area is 11 °C while the maximum is 33.3 °C with little variation throughout the year (Meteorological department, Wakiso district H/Q weather station). The vegetation cover is varied ranging from medium altitude evergreen forest, medium altitude moist deciduous forests, savannas and swamps (Wakiso final report 2009). The crops grown in this area include: vegetables, fruits, bananas, cassava, sweet potatoes, maize and many others.

3.2 Research design

The area comprised of eight parishes; and these are; Kiwenda, Gguluddene, Wamirongo, Kikoko, Magyigye, Busukuma, Kabumba and Lugo (www./cmt.org/uganda/Wakiso). The research scope focused on five parishes namely Kiwenda, Kabumba, Magyigye, Kikoko and Wamirongo. These parishes were purposively selected because they are traditionally the biggest cassava growers in the Sub County. In the parishes, total of 78 cassava fields were randomly selected with a distance of about 1km between fields along motorable roads. Cassava fields with their age ranging between three to twelve months after planting (MAP) were selected. Also, fields with cassava as a predominant crop and varieties that can easily be identified were used in this study. A sampling tool was used to collect the required data (refer to the appendix). During the survey, farmers were interviewed to confirm information about the varieties of cassava and other crops that they were growing as well as associated management activities. Field size of not less than approximately a quarter an acre and not exceeding 4 acres was considered for the study.

3.3 Data collection

30 plants per field were randomly selected using a Z configuration (Wydra and Msikita, 1998). Before sampling in each field, data collectors sought permission from the farmers in order to have access to the field. On each plant, four leaves ranging from position 14^{th} – 24^{th} were carefully assessed for both adult and nymphs of *P. bondari*. The *P. bondari* adults were identified basing on their unique physical characteristics as described by Omongo *et al* (2018) to differentiate them from the other whitefly species in the fields. Then, the adults were then counted on the underside of the leaves and recorded. Since the nymphs were smaller and unable to be easily seen using a naked eye, an X10 magnifying lens was used (NaCRRI adopted whitefly assessment protocol, 2018). The improved cassava varieties were identified by their known morphological characteristics while the local varieties were identified with consultation from the host the farmers. Associated data on crop age, predominant cassava variety, other cassava varieties present, cropping system (monocrop or intercrop), size of cassava field, presence of nearby cassava fields was recorded. GPS coordinates were also recorded and noted down using a handset GPS recorder.

3.4 Data analysis

Abundance data was summarized using descriptive statistics with means presented with charts. All variables were tested for normality using Shapiro-Wilk test and where necessary, the strongly skewed variables were log (log (x +1)) transformed prior to analyses of variance to meet the assumption of normality and homogeneity of variances. The differences among varieties in *P. bondari* abundance was compared using analysis of variance (ANOVA), with post-hoc means separation tested using Tukey (HSD) at 5% probability level. Parishes and variety interactions in *P. bondari* abundance were tested with General Linear Model (GLM) analysis of variance (ANOVA). Where the GLM test indicated significant differences, post-hoc Tukey (HSD) test was used. Pearson's linear regressions were used to assess the relationship between *P. bondari* abundance and crop age, *B.tabaci* and CMD severity. The analyses were implemented using R software version 3.5.0 (R Core Team (2020).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

4.1.1 *P. bondari* population across five Parishes.

There was a significant difference ($F_{4, 2215} = 30.27$, $P = 0.000$) in the mean abundance of *P. bondari* among the five Parishes. The highest *P. bondari* infestation was recorded in Kiwenda, while the least was in Magigye parish (Table 2). Posthoc means separation showed that infestation in Kikoko and Kiwenda were not significantly different, but they were different with the rest of the Parishes (Table 2). Wamirongo and Kabumba were not significantly different, and the latter was not also significantly different from Magigye. Wamirongo was significantly different from Magigye (Table 2 and 3). The highest significant difference was between Kiwenda vs Magigye, and Kiwenda and Wamirongo (Table 3).

Table 2: Infestation by *P. bondari* in the five Parishes in Busukuma Sub County

Parish	Mean (counts/leaf)	SE	Df	lower.CL	upper.CL	Rank
Magigye	0.0708	0.219	2215	-0.491	0.633	a
Kabumba	0.2444	0.291	2215	-0.505	0.994	ab
Wamirongo	0.3769	0.242	2215	-0.246	1	b
Kikooko	1.4933	0.195	2215	0.991	1.996	c
Kiwenda	2.0021	0.219	2215	1.44	2.564	c

Table 3: Pairwise mean differences in infestation by *P. bondari* across the five Parishes in Busukuma Sub County.

Contrast	Difference	SE	Df	t. ratio	p. value
Kabumba – Kikooko	-1.249	0.351	2215	-3.559	<.0001
Kabumba – Kiwenda	-1.758	0.364	2215	-4.826	<.0001
Kabumba – Magigye	0.174	0.364	2215	0.477	0.7427
Kabumba – Wamirongo	-0.132	0.379	2215	-0.349	0.7388
Kikooko – Kiwenda	-0.509	0.293	2215	-1.735	0.6582
Kikooko – Magigye	1.423	0.293	2215	4.852	<.0001
Kikooko – Wamirongo	1.116	0.311	2215	3.585	<.0001
Kiwenda – Magigye	1.931	0.309	2215	6.249	<.0001
Kiwenda – Wamirongo	1.625	0.326	2215	4.979	<.0001
Magigye – Wamirongo	-0.306	0.326	2215	-0.938	0.0442

4.1.2 Effect of Cassava Variety on the population of *P. bondari*

There was a significant difference ($F_{4, 2215}$ = 32.83, P = 0.000) in the mean abundance of *P. bondari* among the five varieties. The highest *P. bondari* infestation was recorded in NAROCASS, while the least was in TME 204 variety (Table 4). Post hoc means separation showed that TME 204, NASE 14 and TME 14 were not significantly different in infestation, but they were different from the rest of the varieties (Table 5). Locals and NAROCASS were also significantly different (Table 4 and 5). The highest significant difference was between NAROCASS vs TME 204 (Table 5).

Table 4: Infestation by *P. bondari* in the five studied varieties in Busukuma Sub County

Variety	Mean (Counts/leaf)	SE	df	lower.CL	upper.CL	Ranks
TME 204	0	0.506	2215	-1.301	1.301	a
NASE 14	0.0667	0.331	2215	-0.785	0.918	a
TME 14	0.1467	0.226	2215	-0.435	0.728	a
Local	1.0011	0.163	2215	0.583	1.419	b
NAROCASS	1.9217	0.196	2215	1.418	2.425	c

Table 5. Pairwise mean differences in infestation by *P. bondari* across the five Parishes in Busukuma Sub County

Contrast	Difference	SE	df	t. ratio	p. value
Local – NAROCASS	-0.9205	0.255	2215	-3.614	<.0001
Local - NASE 14	0.9345	0.369	2215	2.533	0.0003
Local - TME 14	0.8545	0.279	2215	3.066	0.0001
Local - TME 204	1.0011	0.531	2215	1.884	0.013
NAROCASS - NASE 14	1.855	0.385	2215	4.821	<.0001
NAROCASS - TME 14	1.775	0.299	2215	5.931	<.0001
NAROCASS - TME 204	1.9217	0.542	2215	3.542	<.0001
NASE 14 - TME 14	-0.08	0.401	2215	-0.199	0.9591
NASE 14 - TME 204	0.0667	0.605	2215	0.11	0.9991
TME 14 - TME 204	0.1467	0.554	2215	0.265	0.9388

4.1.3 Effect of variety mixing on the *P. bondari* population

There was a significant difference ($F_{6, 2213} = 25.75$, $P = 0.000$) in the mean abundance of *P. bondari* among the seven varietal mixes. The highest *P. bondari* infestation was recorded in NAROCASS, while the least were in NAROCASS+Local+TME, and Local+TME varietal mixes (Table 6). Posthoc means separation showed that Local+TME, TME and Local+NASE 14 were not significantly different in infestation. Similarly, TME+NAROCASS, NAROCASS+Local+TME, and Local were not significantly different (Table 7). NAROCASS was significantly different from the rest of the mixes (Table 6 and 7).

Table 6: Infestation by *P. bondari* in the seven common variety mixes in Busukuma Sub County

Variety mix	Mean (Log) (counts/leaf)	SE	Df	lower.CL	upper.CL	Ranks
Ncas+L+TME	0	0.0344	2213	-0.09248	0.0925	Ab
L+TME	0.00466	0.0218	2213	-0.05383	0.0632	A
TME	0.02439	0.0184	2213	-0.02505	0.0738	A
L+Nas	0.03777	0.0154	2213	-0.00359	0.0791	A
TME+Ncas	0.04136	0.0184	2213	-0.00808	0.0908	Ab
L	0.09767	0.0092	2213	0.07296	0.1224	B
Ncas	0.21613	0.0126	2213	0.18236	0.2499	C

L=Local, TME= TME14&TME 204, Nas=NASE14, Ncas=NAROCASS

Table 7: Pairwise mean differences in infestation by *P. bondari* across the seven common variety mixes in Busukuma Sub County.

Contrast	Difference	SE	Df	t. ratio	p. value
L - L+Nas	0.7702	0.322	2213	2.394	0.015
L - L+TME	1.0102	0.424	2213	2.383	0.0017
L – Ncas	-1.3387	0.279	2213	-4.791	<.0001
L - Ncas+L+TME	1.0369	0.639	2213	1.622	0.0891
L – TME	0.8655	0.369	2213	2.345	0.0069
L - TME+Ncas	0.8274	0.369	2213	2.242	0.0899
L+Nas - L+TME	0.24	0.478	2213	0.502	0.878
L+Nas – Ncas	-2.1089	0.357	2213	-5.915	<.0001
L+Nas - Ncas+L+TME	0.2667	0.676	2213	0.394	0.9538
L+Nas – TME	0.0952	0.43	2213	0.221	0.9979
L+Nas - TME+Ncas	0.0571	0.43	2213	0.133	1
L+TME – Ncas	-2.3489	0.451	2213	-5.208	<.0001
L+TME - Ncas+L+TME	0.0267	0.731	2213	0.036	1
L+TME – TME	-0.1448	0.511	2213	-0.283	0.9931
L+TME - TME+Ncas	-0.1829	0.511	2213	-0.358	0.8582
Ncas - Ncas+L+TME	2.3756	0.657	2213	3.614	<.0001
Ncas – TME	2.2041	0.4	2213	5.514	<.0001
Ncas - TME+Ncas	2.166	0.4	2213	5.418	<.0001
Ncas+L+TME – TME	-0.1714	0.7	2213	-0.245	0.996
Ncas+L+TME - TME+Ncas	-0.2095	0.7	2213	-0.299	0.9398
TME - TME+Ncas	-0.0381	0.467	2213	-0.082	0.995

4.1.4 The overall effect of Intercropping on the population of *P. bondari*

There was a significant difference (t = -6.7781, df = 901.81, p-value = 2.198e-11) in mean abundance of *P. bondari* between cassava Intercrop (0.61 ± 0.1) and Monocrop (1.75 ± 0.2). Infestation was higher in the monocropped than intercropped fields (figure 3)

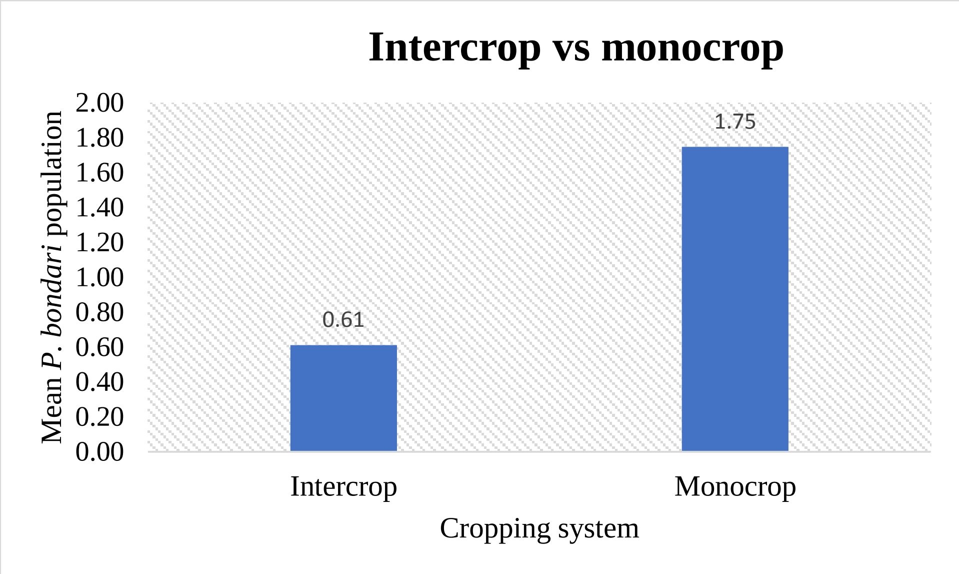

Figure 3: Variability of mean *P. bondari* abundance in different cropping systems.

4.1.5 Effect of proximity to other cassava fields on *P. bondari* population in different cropping systems

When a relationship between monocrops, intercrops and nearby cassava fields in relation to *P. bondari* abundance was determined, monocrops recorded lower infestation when planted in isolation from other cassava fields, compared to Intercrops (Figure 4). However, when planted in close proximity to other cassava fields, Intercrops recorded significantly lower infestation, while Monocrops recorded significantly higher infestations from the overall (Figure 4). There was a significant difference (t = -4.282, df = 1557.1, p-value = 1.965e-05) in mean abundance of *P. bondari* between gardens which were surrounded by other cassava gardens (1.124± 0.12), than those that were not (0.472± 0.198). Locals recorded higher, but not significant infestation when planted in isolation from other cassava fields. NAROCASS recorded lower, but not significant infestation when planted in isolation from other cassava fields. In the converse, NASE 14, TME 14 and TME 204 recorded significantly lower infestations when planted in isolation from other cassava fields (Figure 6). However, when planted in close proximity to other cassava fields, NAROCASS recorded significantly higher infestation, while NASE 14, TME 14 and TME 204 recorded significantly lower infestations overall (Figure 5).

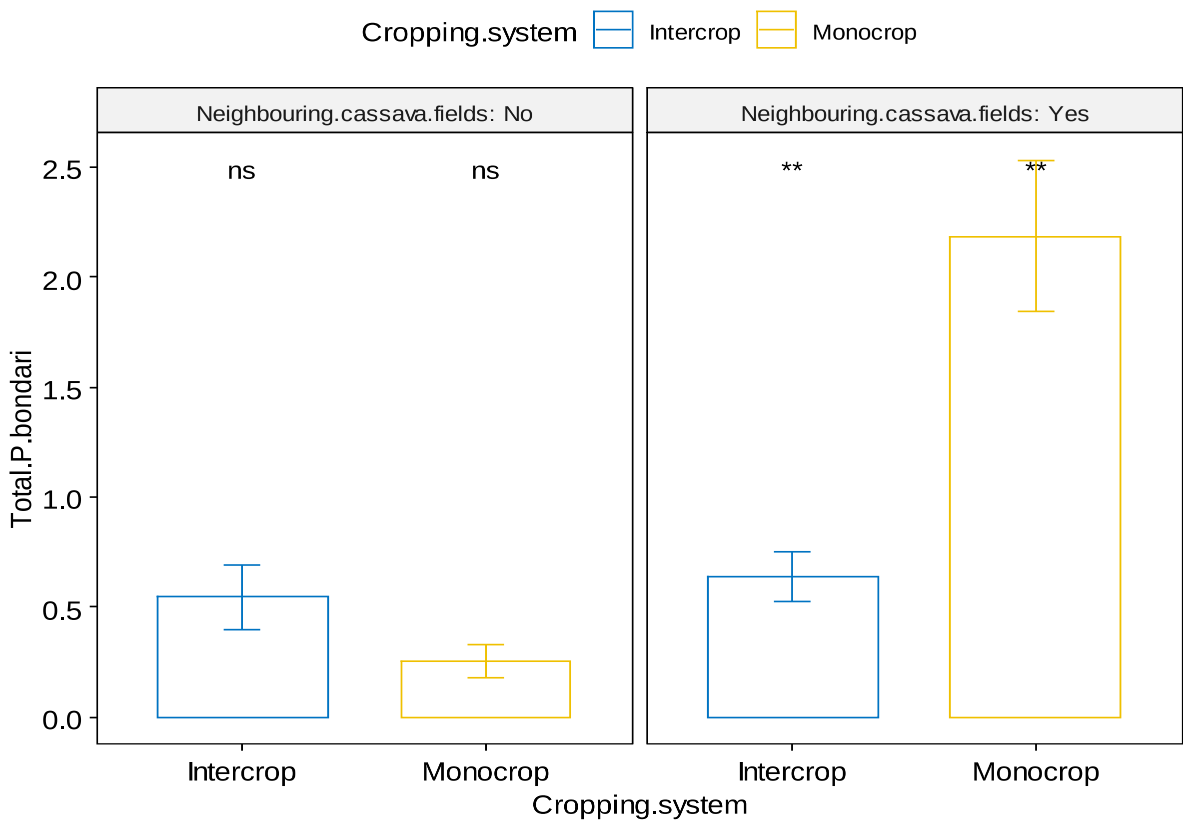

Figure 4: Variability in incidence of *P. bondari* among Intercrops and Monocrops with and without proximity to other cassava varieties. Ns implies not significant.

4.1.6 Effect of neighbouring cassava fields on *P. bondari* population on cassava type and different cassava varieties

There was a significant difference ($t = -4.2444$, $df = 1521.9$, p-value = 0.000) in mean abundance of *P. bondari* between local (1.367 ± 0.16) and improved (0.662 ± 0.13) cassava varieties. Improved varieties recorded significantly ($P < 0.05$) lower infestation when planted in isolation from other cassava fields, compared to locals (Figure 5). However, when planted in close proximity to other cassava fields, both improved and local varieties recorded higher infestation, although they were not significantly different from the overall (Figure 5). Locals recorded higher, but not significant infestation when planted in isolation from other cassava fields. NAROCASS recorded lower, but not significant infestation when planted in isolation from other cassava fields. In the converse, NASE 14, TME 14 and TME 204 recorded significantly lower infestations when planted in isolation from other cassava fields (Figure 6). However, when planted in close proximity to other cassava fields, NAROCASS recorded significantly higher infestation, while NASE 14, TME 14 and TME 204 recorded significantly lower infestations overall (Figure 6).

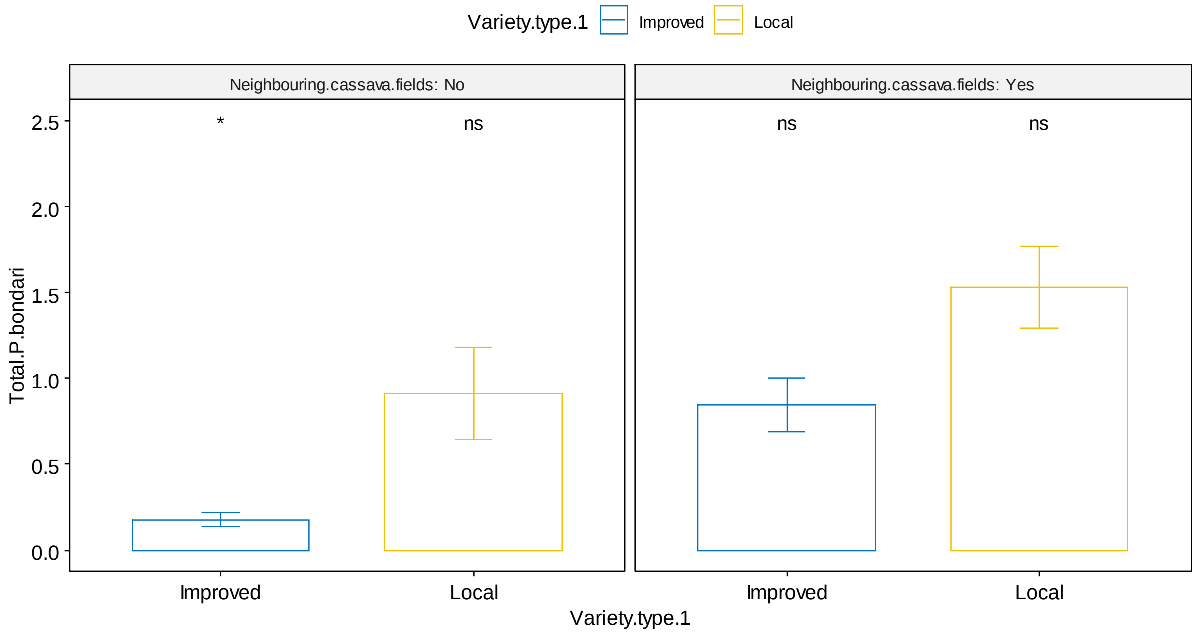

Figure 5: Variability in incidence of *P. bondari* among improved and local varieties with and without proximity to other cassava varieties.

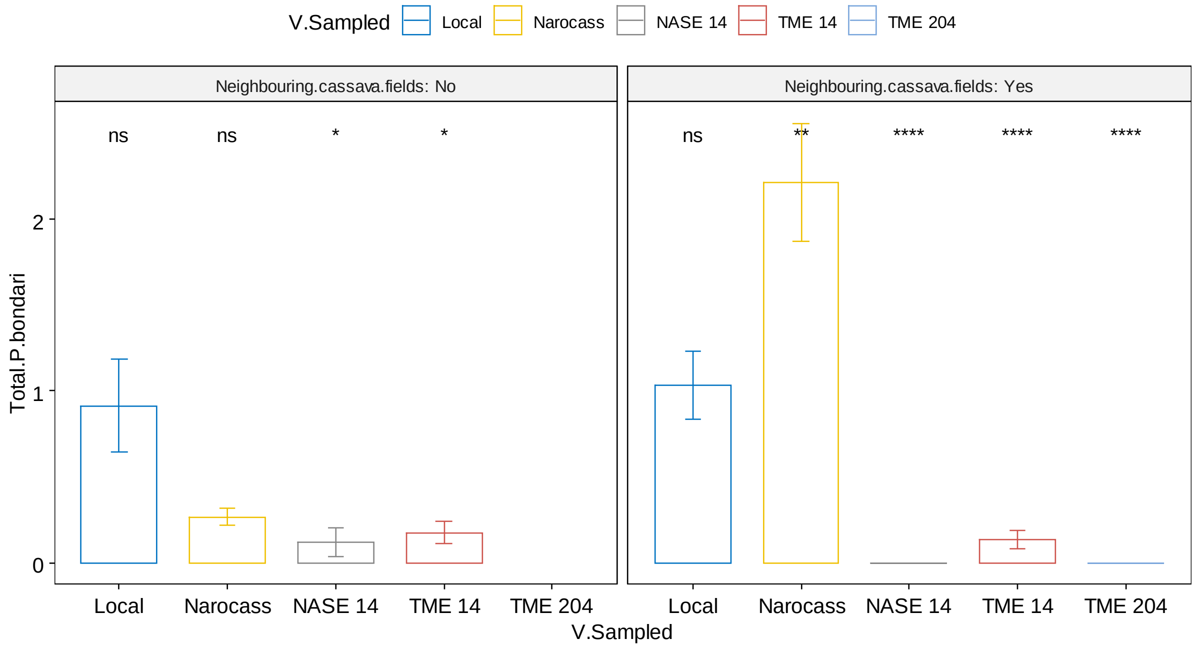

Figure 6: Variability in incidence of *P. bondari* among Varieties with and without proximity to other cassava varieties. Ns implies not significant.

4.1.7 Occurrence of *P. bondari* with crop age, *B. tabaci* abundance and cassava mosaic disease severity

There abundance of *P.bondari* did not change with variation in crop age (Figure 7). Among Varieties, NASE14 and TME14 showed significant and positive relationship between cassava crop age and *P. bondari* abundance, while the TME 204 numbers recorded were too small to make any relationship between crop age and *P. bondari* abundance (Figure 8). The abundance of *B. tabaci* and CMD severity were not significantly related to the abundance and distribution of *P. bondari.*

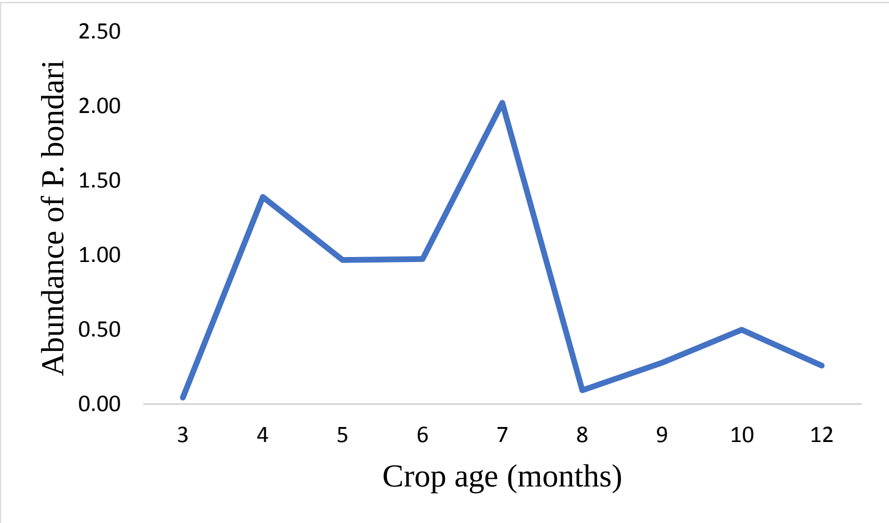

Figure 7: Cassava crop age (Months) and *P. bondari* abundance in Busukuma Sub County

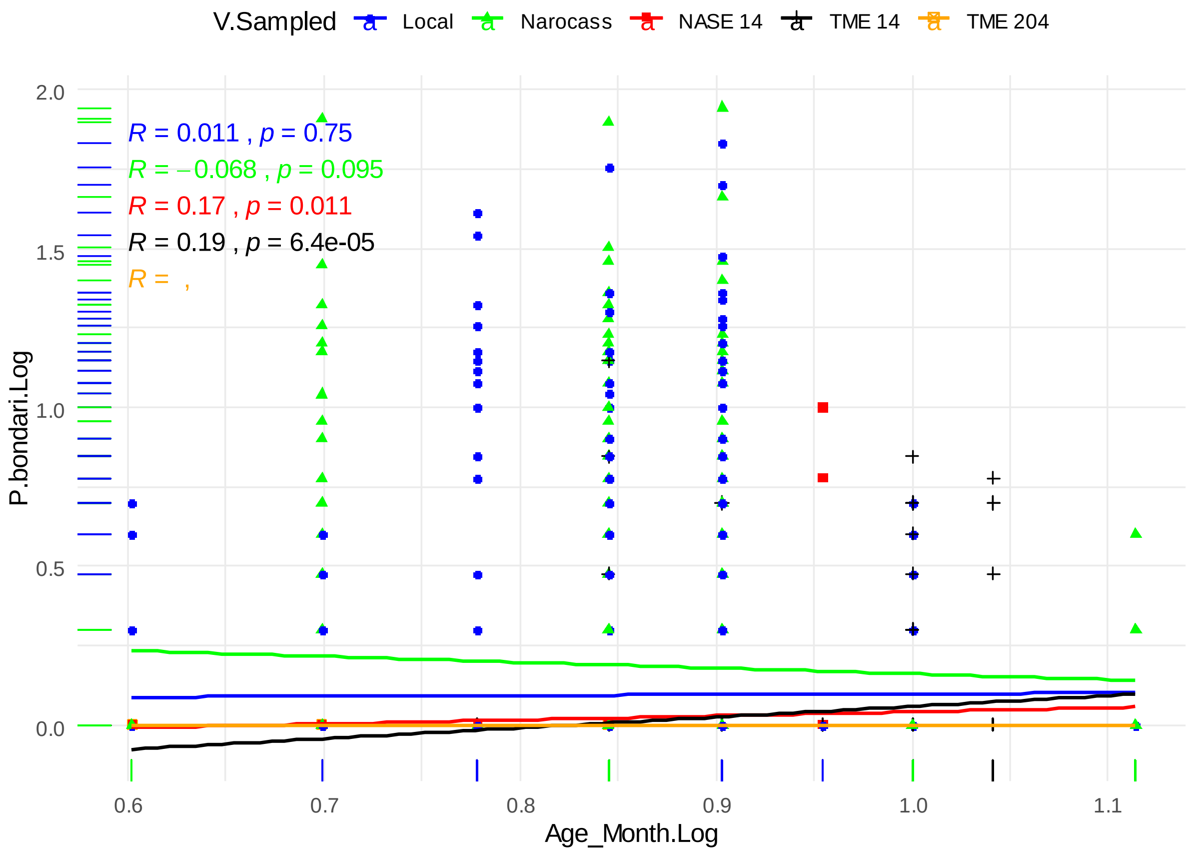

Figure 8: Occurrence of *P. bondari* across different crop age

4.2 Discussion of results

4.2.1 *P. bondari* abundance across five Parishes

This study assessed *P. bondari* abundance among the five parishes. Whiteflies can travel over short distances to feed and breed or they can disperse passively over long distances to new areas with the aid of wind currents, can even be dispersed over long distances through infested planting materials. The differences observed could be due to the fact that different parishes offer different resource types and in varying concentrations, in addition to the obvious ecological and climatic differences and farmer practices. Similar trend was observed in the studies of other whiteflies (*Bemisia tabaci*) concerning their abundance variations across different locations (Jeremiah *et al*., 2014; Macfayden *et al*., 2020).

Furthermore, the variations could be attributed to the different cassava varieties grown in the different parishes, the different variety combinations, different cropping systems and different altitudes. Kikooko and Kiwenda which had the highest infestation of *P. bondari* were also predominantly covered with NAROCASS and local varieties which are the most preferred varieties for the *P.bondari*, while Magigye and Kabumba which had the least infestation of *P. bondari* was predominantly covered with TME 14 which was not preferred by *P. bondari*. In East Africa, (Macfadyen *et al*., 2020) showed that another species of white fly (*Bemisia tabaci*) exhibited different infestation levels on different cassava varieties.

4.2.2 Effect of Cassava variety on the abundance of *P. bondari*

In this study different *P. bondari*population sizes were observed on the different cassava varieties, with NAROCASS having the highest population while TME 204 had the least. Whiteflies are resilient pests with typical ecological adaptiveness. They may differ in distribution patterns and host utilization preferences but most species can survive, with some degree of flexibility, in a wide range of habitats of varying environmental conditions. The variation may be due to differences in the physical and chemical properties of the different genotypes. This result is in line with other studies of different whitefly species (*Bemisia tabaci*) (Macfadyen *et al*., 2020). These differences among the cassava genotypes can lead to preferential differences by the *P.bondari* hence leading to different infestation levels. The differences in the abundance levels of *P. bondari* between local and improved recorded in this study can be explained by the differences in the genetic composition of the varieties. Generally, the improved varieties have lower infestation levels compared to the local varieties, this can be due to the reason that the genetic composition of improved varieties has been altered to increase their resistance to whiteflies, hence the low levels of abundance with the exception of NAROCASS which has very high *P. bondari* populations. Similar studies have been carried out on other insect pests, for instance the case of fruit flies (*Bactrocera invadens*), it has been suggested that this species of fruitflies is able to discriminate among the mango varieties based on pre-alighting factors such as host colors, which play an important role on oviposition sit selection (Katsoyannos, 2001).

The high *P. bondari* populations in the NAROCASS may need further studies to reveal factors influencing the preference of *P. bondari* for this improved variety. The high local variety cultivation across the country in general including my area of study exhibits a high resource concentration for the *P. bondari*. In order to be well adapted to their new area of colonization, *P.bondari* needs to establish a good relationship between the host which is abundantly available and hence the high *P. bondari* on the locals. It has been investigated on

Bemisia tabaci whitefly species that previous experience of the whitefly on a given host plant affects their host selection and performance on the plants without previous experience (Shah and Liu, 2013). The increasing levels of infestation *P. bondari* of both improved and locals when planted near other cassava fields is due to the fact that these other fields act as sources of *P. bondari* infestation.

4.2.3 Effect of Intercropping, Variety mixing and proximity to other cassava gardens on the abundance of *P. bondari*

This study also revealed that monocrops had higher infestation as compared to intercrops. This is consistent with observations by Gold (1994) who reported lower whitefly populations in cassava intercropped with cowpea than in monocrop cassava in Colombia. In Cameroon, Fondong *et al*., (2002) showed that intercropping cassava with maize or cowpea reduced whitefly populations. In another study Fargette and Fauquet (1988) concluded that intercropping effects were not merely due to maize acting as a barrier sheltering cassava from incoming whiteflies but were due to whitefly vector populations and possibly whitefly vector activity. However, the trend in the levels of infestation of *P. bondari* in both monocrops and intercrops changed when planted in close proximity to other cassava fields. This is due to the presence of other cassava fields which act as sources of *P. bondari*, and because there is genetic diversity in the intercrop, factors such as parasites, predators, masking, camouflage, repellency, less colonization, resource concentration, unfavorable microclimate, physical obstruction and trap cropping help to explain the *P. bondari* reduction levels in the intercrops. In the monocrops where there is limited genetic variability easily accumulate *P.bondari* when planted near other cassava fields. It has been suggested that ecological flexibility is a key trait in ecological success of species, and it has been found to respond to several volatile chemical cues involved in foraging and habitat choice (Honek and Martinkova, 2008; Pettersson *et al*., 2008). Planting a number of different cassava variety mixes showed different *P.bondari* levels is due to increasing genetic diversification, but also different synergist effects created by the different variety combinations. Studies have established that chemicals released by herbivore or pathogen damaged plants can induce responses in neighboring plants that affect interactions with insect herbivores and their natural enemies (Dicke *et al*., 2003; Baildwin *et al*., 2006). These differences lead to different *P. bondari* levels among the different mixes where some combinations relatively lower levels due to stronger synergism in resisting *P. bondari* colonization as compared to other mixes.

4.2.4 Occurrence of *P. bondari* with crop age, *B. tabaci* abundance and cassava mosaic disease severity

This study shows that there was generally no correlation between crop age and abundance, previous studies also revealed that there was no correlation between crop age and studies on different white fly species (*Bemisia tabaci*) (Kalyebi *et al*., 2018), but some recent studies contradicts with the above findings as they showed that there was a positive relationship between whitefly abundance and crop age (Macfayden., 2020). Notably too in this study *P.bondari* preference among the different cassava varieties at different ages also showed variations here some varieties like NASE 14 and TME 14 exhibited increasing *P.bondari* populations as the cassava matures while other varieties namely: locals, Narocass and TME 204 did not show differences in the *P. bondari* abundance as they matured. For *Bemisia tabaci*, similar findings by (Kalyebi *et al*., 2018) have reported that whitefly infestation varied with different cassava variety. Several studies have revealed that behavioral and ecological factors (biotic and abiotic) play an important role in host use (Khan *et al*., 2000). The variations in the *P.bondari* abundance among the different cassava varieties as the crop age varies may be explained by changes in leaf color, leaf texture, leaf size, leaf structure and changes in the chemical compounds of the crop as the cassava grows. A conjugation of plant physical and chemical factors influences the choice and balance between positive and negative stimuli, might ultimately determine the host selection. It is therefore possible that *P. bondari* is able to discriminate the cassava varieties based on physical and chemical properties which play an important role in the egg laying site selection, thus further investigative studies into the biochemical composition variations as age varies and their relationships with *P. bondari* abundance so as to further enlighten the cassava variety/ *P. bondari* population variations. In barley, it has been demonstrated that volatile interactions between undamaged barley plants of different genotypes made them less acceptable to aphids (Ninkovic *et al*., 2002, 2009; Glinwood *et al*., 2007, 2009; Kellner *et al*., 2010).

This study revealed that as the crop diversity increased, the *P. bondari* abundance decreased. Species of crop plant can affect organisms of that use the plants as hosts (Mundt, 2002; Ninkovic *et al*., 2002; Cadet *et al*.,2007), this may be due to factors such as parasites, predators, masking, camouflage, repellency, less colonization, resource concentration, unfavorable microclimate, physical obstruction and trap cropping, however studies on *Bemisia tabaci* whitefly species revealed negative significant relationship between crop diversity and whitefly abundance (Frank and Liburd (2005)) while other studies on *Bemisia tabaci* whitefly species showed no significant relationship between crop diversity and whitefly abundance (Smith and McSorley (2000) and Smith et al. (2000, 2001). The different observations were partially due to the polyphagous nature of the *Bemisia tabaci* nature, hence since different studies have revealed different host ranges for *P. bondari*. This suggests that it is a polyphagous pest too hence more research involving different crop diversifications to get a more profound effect of crop diversification on abundance.

The abundance of *P. bondari* was not related to *Bemisia tabaci* abundance, hence showing that the two different whitefly species maybe mutually exclusive which means that the presence on *P. bondari* in a place does not depend on the presence of *Bemisia tabaci* and vice versa. The correlation between *P. bondari* abundance and Cassava mosaic virus disease (CMD) severity which suggest that there are major factors influencing CMD severity other than *P. bondari*, or it may also suggest that *P. bondari* whitefly species if it is a vector of CMD maybe not be an efficient transmitter as compared to other whitefly species (*Bemisia tabaci*) in the area. From the above results, there is need to find out if *P. bondari* is a vector of CMD and also to determine the major drivers of CMD severity in the cassava fields.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The study noted variability in cassava varietal infestation with Narocass and Locals being the most infested and TME 204 and NASE14 the least. Variations in the *P. bondari* abundance also occurred among different locations in Busukuma Sub County with Kiwenda having the highest occurrence and Magigye having the least occurrence. There were differences in cropping systems and varietal mixes that showed that intercrops and varietal mixes reduced *P. bondari* infestation.

5.2 Recommendations

I. This study concentrated on a small area (Sub County), therefore further studies on a wider area to improve the knowledge of ecological aspects of *P. bondari* whiteflies in the different agro ecological and adapho-climatic conditions of Uganda.

II. Further behavioral and ecological research to confirm or refute whether the observed variety and geographic differences have genetic and behavioral relationships.

III. Further studies should consider both variety-specific variations in adult and offspring performance, and focus on testing a wider range of varieties for the development of *P. bondari*. An assessment of the chemical components of the different cassava varieties can help understand the mechanism of variety suitability.

IV. Further studies involving a wider range of hosts in order to determine the host-specific variations since this study focused on only cassava as a host

REFERENCES

Adjebeng-Danquah, J., Acheremu, K., Asante, S. K., Kusi, F., & Osei, C. (2012). Evaluation of early bulking cassava accessions for high yield potential for the Guinea Savannah Zone of Ghana. *Ghana J Agric Sci*, *45*, 61-70.

Allem, A. C. (2002). The origins and taxonomy of cassava. *Cassava: biology, production and utilization*, *1*, 1-16.

Anderson, P. K., & Morales, F. (2005). Whitefly and whitefly borne viruses in the tropics: building a knowledge base for global action. Publication CIAT No. 341, Cali, Colombia. *International Center for Tropical Agriculture*.

Avidov, Zo. "Bionomics of the tobacco whitefly (Bemisia tabaci Gennad.) in Israel." Ktavim 7.1 (1956): 23-41.

Bailey H. 1976. Hortus Third. A Concise Dictionary of Plants Cultivated in the United States and Canada. McMillan

Bale, J. S. (2002). Insects and low temperatures: from molecular biology to distributions and abundance. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *357*(1423), 849-862.

Beatriz Vanessa Herrera Campo, Bellotti, Anthony, and Glenn Hyman. "Cassava production and pest management: present and potential threats in a changing environment." Tropical Plant Biology 5.1 (2012): 39-72.

Bellotti, A. C., Braun, A. R., Arias, B., Castillo, J. A., & Guerrero, J. M. (1994). Origin and management of neotropical cassava arthropod pests. *African Crop Science Journal*, *2*(4), 407-417.

Bigirimana, S., Barumbanze, P., Ndayihanzamaso, P., Shirima, R., & Legg, J. P. (2011). First report of cassava brown streak disease and associated Ugandan cassava brown streak virus in Burundi. *New Disease Reports*, *24*(26), 2044-0588.

Bock, K. R. "Woods (1983) Etiology of African cassava mosaic disease." Plant disease 67: 994-995.

Boykin, Laura M., and Paul J. De Barro. "A practical guide to identifying members of the Bemisia tabaci species complex: and other morphologically identical species." Frontiers in Ecology and Evolution 2 (2014): 45.

Byrne, David N., and Thomas S. Bellows Jr. "Whitefly biology." Annual review of entomology 36.1 (1991): 431-457.

Campbell, Bruce C., et al. "Determining whitefly species." Science 261.5126 (1993): 1333-1336.

Chakraborty, Ardhendu, K. Kumar, and D. J. Pal. "Received: 04 th Feb-2014 Revised: 27 th Feb-2014 Accepted: 28 th Feb-2014 Research article impact of certain agrochemicals on the population of coccinellid beetles (coleoptera: coccinellidae) in bhendi (abelmoschus esculentus (l.) moench) ecosystem."

Charles, E. (2010). Systematics of whiteflies (Aleyrodidae: Aleurodicinae): their distribution, phylogeny and relationship with parasitoids.

Clark, Marta A., et al. "The eubacterial endosymbionts of whiteflies (Homoptera: Aleyrodoidea) constitute a lineage distinct from the endosymbionts of aphids and mealybugs." Current Microbiology 25.2 (1992): 119-123.

Col, Jeananda. "Enchanted learning." Tropical Rainforest Strata: Label Me (2001).

Coursey, D. G. (1973). Cassava as food: toxicity and technology. In *Chronic cassava toxicity*. IDRC, Ottawa, ON, CA.

Cruz Castiblanco, G. N., Varon Devia, E. H., Quiroga Rojas, L. F., Andrade, B. M., & Sierra Baquero, P. V. (2016). Related factors to the Paraleyrodes sp. pos. bondari (Hemiptera: Aleyrodidae) population in avocado. *Revista Colombiana de Entomología*, *42*(2), 103-109.

Dahniya, M. T. (1994). An overview of cassava in Africa. *African Crop Science Journal*, *2*(4), 337-343.

De Barro, Paul J., et al. "Phylogenetic relationships of world populations of Bemisia tabaci (Gennadius) using ribosomal ITS1." *Molecular phylogenetics and evolution* 16.1 (2000): 29-36.

DeVries, J., & Toenniessen, G. H. (2001). *Securing the harvest: biotechnology, breeding, and seed systems for African crops*. CABI.

Dickey, A. M., Stocks, I. C., Smith, T., Osborne, L., & McKenzie, C. L. (2015). DNA barcode development for three recent exotic whitefly (Hemiptera: Aleyrodidae) invaders in Florida. *Florida Entomologist*, 473-478.

FAOSTAT (2011) Food and agricultural commodities production. Food and Agriculture Organization of The United Nations Statistics Database. Available at: http://faostat.fao.org/ (accessed 1 April 2011).

Faostat, F. A. O. (2020). Crops. *Food and Agriculture Organization of the United Nations. Available online at*.

Fargette, Denis, and Claude Fauquet. "A preliminary study on the influence of intercropping maize and cassava on the spread of African cassava mosaic virus by whiteflies." Aspects of Applied Biology 17 (1988): 195-202.

Fauquet, C. M., & Tohme, J. (2008). Global cassava partnership for 21st century for genetic improvement. In *Annual meetings abstracts. Danforth Plant Center, ILTAB, St Louis (USA)* (Vol. 14).

Fishpool, L. D. C., and C. Burban. "Bemisia tabaci: the whitefly vector of African cassava mosaic geminivirus." Tropical Science 34.1 (1994): 55-72.

Fishpool, L. D. C., et al. "The phenology of Bemisia tabaci (Homoptera: Aleyrodidae) populations on cassava in southern Côte d'Ivoire." Bulletin of Entomological Research 85.02 (1995): 197-207.

Frohlich, D. R., et al. "A phylogeographical analysis of the Bemisia tabaci species complex based on mitochondrial DNA markers." Molecular ecology 8.10 (1999): 1683-1691.

Gawel, N. J., and A. C. Bartlett. "Characterization of differences between whiteflies using RAPD-PCR." Insect molecular biology 2.1 (1993): 33-38.

Gill, R. J. "The morphology of whiteflies." Whiteflies: their bionomics, pest status and management. Andover: Intercept (1990): 13-46.

Gold, C. S. (1994). The effects of cropping systems on cassava whiteflies in Colombia: implications for control of African cassava mosaic virus disease. *African Crop Science Journal*, *2*(4), 423-436.

Guirao, P., F. Beitia, and J. L. Cenis. "Biotype determination of Spanish populations of Bemisia tabaci (Hemiptera: Aleyrodidae)." Bulletin of Entomological Research 87.06 (1997): 587-593.

Hahn, S. K., Reynolds, L., & Egbunike, G. N. (Eds.). (1992). *Cassava as Livestock Feed in Africa: Proceedings of the IITA/ILCA/University of Ibadan Workshop on the Potential Utilization of Cassava as Livestock Feed in Africa: 14-18 November 1988, Ibadan, Nigeria*. Iita.

Hammer, Ø., Harper, D. A., & Ryan, P. D. (2001). PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia electronica*, *4*(1), 9.

Hillocks, R. J., & Wydra, K. (2002). Bacterial, fungal and nematode diseases. *Cassava: biology, p*

Hillocks, R. J., and D. L. Jennings. "Cassava brown streak disease: a review of present knowledge and research needs." International Journal of Pest Management 49.3 (2003): 225-234.

Hillocks, R. J., Raya, M. D., Mtunda, K., & Kiozia, H. (2001). Effects of brown streak virus disease on yield and quality of cassava in Tanzania. *Journal of Phytopathology*, *149*(7-8), 389-394.

Hodkinson, I. D. (2005). Terrestrial insects along elevation gradients: species and community responses to altitude. *Biological reviews*, *80*(3), 489-513.

Husain, M. Afzal, and Kidar Nath Trehan. "Observations on the life-history, bionomics and control of the white-fly of cotton (Bemisia gossypiperda M. & L.)." Indian J. Agric. Sci 3.4 (1933): 701-753.

Iaccarino, F. M., Jesu, R., & Giacometti, R. (2011). Paraleyrodes minei Iaccarino 1990 (Homoptera: Aleyrodidae), new specie for Italy, on Citrus aurantium L., 1758. *Journal of Entomological and Acarological Research*, *43*(1), 1-6.

International Atomic Energy Agency, Cassava Production Guidelines for Food Security and Adaptation to Climate Change in Asia and Africa, IAEA-TECDOC-1840, IAEA, Vienna (2018).

Katsoyannos, B. I., & Kouloussis, N. A. (2001). Captures of the olive fruit fly Bactrocera oleae on spheres of different colours. *Entomologia Experimentalis et Applicata*, *100*(2), 165-172.

Kaweesi, T., Kawuki, R., Kyaligonza, V., Baguma, Y., Tusiime, G., & Ferguson, M. E. (2014). Field evaluation of selected cassava genotypes for cassava brown streak disease based on symptom expression and virus load. *Virology journal*, *11*(1), 216.

Kimathi, M., Ngeli, P., Wanjiru, J. (2007). Value chain analysis for cassava flour and related products: A case of Uganda and Kenya. Farm Concern International final report: Analyzing value chains for specific commodities. www.farmconcern.org., Accessed on 3th March, 2014

Kleih, U., Phillips, D., Jagwe, J., Kirya, M., & Innovations, A. (2012). Cassava Market and Value Chain Analysis Uganda Case Study. *Natural Resources Institute (NRI) and Africa Innovations Institute (AII). URL http://cava. nri. org/images/documents/publications/UgandaCassavaMarketStudy-FinalJuly2012_anonymised-version2. pdf (last accessed: 04.03. 2016).*

Kutuk, Halil, Abdurrahman Yigit, and Ozdemir Alaoglu. "The effect of season on the levels of predation by the ladybird Serangium parcesetosum Sicard (Coleoptera: Coccinellidae) on the cotton whitefly Bemisia tabaci (Genn.) (Homoptera: Aleyrodidae), a serious pest of eggplants." Journal of pest science 81.4 (2008): 207-212.

Langlands, J. 1972. Cassava in Uganda. Uganda Journal 10:273-28

Legg, J. P., & Fauquet, C. M. (2004). Cassava mosaic geminiviruses in Africa. *Plant molecular biology*, *56*(4), 585-599.

Legg, J. P., and S. Ogwal. "Changes in the incidence of African cassava mosaic virus disease and the abundance of its whitefly vector along south–north transects in Uganda." Journal of Applied Entomology 122.1-5 (1998): 169-178.

Legg, J. P., et al. "A distinct Bemisia tabaci (Gennadius)(Hemiptera: Sternorrhyncha: Aleyrodidae) genotype cluster is associated with the epidemic of severe cassava mosaic virus disease in Uganda." Molecular Ecology 11.7 (2002): 1219-1229.

Legg, J. P., Sseruwagi, P., Boniface, S., Okao-Okuja, G., Shirima, R., Bigirimana, S., ... & Ndyetabula, I. (2014). Spatio-temporal patterns of genetic change amongst populations of cassava Bemisia tabaci whiteflies driving virus pandemics in East and Central Africa. *Virus research, 186,* 61-75.

Lian, T. S., & Cock, J. H. (1979). Branching habit as a yield determinant in cassava. *Field Crops Research*, *2*, 281-289.

Liburd, O. E., T. W. Nyoike, and J. M. Razze. Biology and management of whiteflies in sustainable field production of cucurbits. ENY-848/IN762, IFAS Extension, University of Florida, Gainesville, 2008.

Longo, S., & Rapisarda, C. (2014). Spread of P araleyrodes minei I accarino (nesting whitefly) in I talian citrus groves. *EPPO Bulletin*, *44*(3), 529-533.

Lysy M, Stasko AD, SwansonHK (2014) nicheROVER: (Niche) (R)egion and niche (Over)lap metrics for multidimensional ecological niches (Version 1.0).

Macfadyen, S., Paull, C., Boykin, L. M., De Barro, P., Maruthi, M. N., Otim, M., ... & Omongo, C. A. (2018). Cassava whitefly, Bemisia tabaci (Gennadius) (Hemiptera: Aleyrodidae) in East African farming landscapes: a review of the factors determining abundance. *Bulletin of entomological research*, *108*(5), 565-582.

Macfadyen, S., Tay, W. T., Hulthen, A. D., Paull, C., Kalyebi, A., Jacomb, F., ... & Kachigamba, D. (2020). Landscape factors and how they influence whitefly pests in cassava fields across East Africa. *Landscape Ecology*, 1-23.

Madeley, J. (1993). Make way for super cassava. *Ceres. The FAO Review (FAO)*.

Malumphy, C., & Mifsud, D. (2016). First record of the nesting whitefly, Paraleyrodes minei Iaccarino, 1990 (Hemiptera, Aleyrodidae) in Malta.

Martin, J. H. (2001). Description of an invasive new species of Neotropical aleurodicine whitefly (Hemiptera: Aleyrodidae)-a case of complete or partial misidentification? *Bulletin of Entomological Research*, *91*(2), 101.

Martin, J. H. (2004). The whiteflies of Belize (Hemiptera: Aleyrodidae) Part 1 - introduction and account of the subfamily Aleurodicinae Quaintance & Baker. Zootaxa, 681, 1–119

Martin, J. H. (2008). A revision of Aleurodicus Douglas (Sternorrhyncha, Aleyrodidae), with two new genera proposed for palaeotropical natives and an identification guide to world genera of Aleurodicinae. *Zootaxa*, *1835*(1), 1-100.

Martin, J. H., & Mound, L. A. (2007). An annotated check list of the world's whiteflies (Insecta: Hemiptera: Aleyrodidae). *Zootaxa*, *1492*(1), 1-84.

Martin, J. H., Mifsud, D., & Rapisarda, C. (2000). The whiteflies (Hemiptera: Aleyrodidae) of Europe and the Mediterranean basin. *Bulletin of entomological research*, *90*(5), 407-448.

Maruthi, M. N., Bouvaine, S., Tufan, H. A., Mohammed, I. U., & Hillocks, R. J. (2014). Transcriptional response of virus-infected cassava and identification of putative sources of resistance for cassava brown streak disease. *PloS one*, *9*(5), e96642.*roduction and utilization*, 261-280.

Mbanzibwa, D. R., et al. "Evolution of cassava brown streak disease-associated viruses." *Journal of General Virology* 92.4 (2011): 974-987.

Mifsud, D., Cocquempot, C., Mühlethaler, R., Wilson, M., & Streito, J. C. (2010). Other Hemiptera Sternorrhyncha (Aleyrodidae, Phylloxeroidea, and Psylloidea) and Hemiptera Auchenorrhyncha.

Mugerwa, H., Seal, S., Wang, H. L., Patel, M. V., Kabaalu, R., Omongo, C. A., ... & Colvin, J. (2018). African ancestry of New World, Bemisia tabaci-whitefly species. *Scientific reports*, *8*(1), 2734.

Navas-Castillo, J., Fiallo-Olivé, E., & Sánchez-Campos, S. (2011). Emerging virus diseases transmitted by whiteflies. Annual review of phytopathology, 49, 219-248.

Nsubuga, F. N. W., Olwoch, J. M., & de W Rautenbach, C. J. (2011). Climatic trends at Namulonge in Uganda: 1947-2009. *Journal of Geography and Geology*, *3*(1), 119.

Nweke, F., Spencer, D. S., & Lynam, J. K. (2002). *The cassava transformation: Africas bestkept secret*.

Olsen, K. M., & Schaal, B. A. (2001). Microsatellite variation in cassava (Manihot esculenta, Euphorbiaceae) and its wild relatives: further evidence for a southern Amazonian origin of domestication. *American journal of botany*, *88*(1), 131-142.

Omongo, C. A. (2003). *Cassava whitefly, Bemisia tabaci, behaviour and ecology in relation to the spread of the cassava mosaic pandemic in Uganda* (Doctoral dissertation, Ph. D. Thesis, University of Greenwich, UK).

Omongo, C. A., Kawuki, R., Bellotti, A. C., Alicai, T., Baguma, Y., Maruthi, M. N., ... & Colvin, J. (2012). African cassava whitefly, Bemisia tabaci, resistance in African and South American cassava genotypes. *Journal of integrative agriculture*, *11*(2), 327-336.

Omongo, C. A., Namuddu, A., Okao-Okuja, G., Alicai, T., van Brunschot, S., Ouvrard, D., & Colvin, J. (2018). Occurrence of Bondar's nesting whitefly, Paraleyrodes bondari (Hemiptera: Aleyrodidae), on cassava in Uganda. *Revista Brasileira de entomologia*, *62*(4), 257-259.

Otekunrin, O. A., & Sawicka, B. (2019). Cassava, a 21st century staple crop: how can Nigeria harness its enormous trade potentials. *Acta Scientific Agriculture*, *3*(8), 194-202.

Otim-Nape, G. W., and S. Zziwa. "Cassava as a Major Staple Food Crop in Uganda." Phase I of collaborative study of cassava in Africa. Namulonge research station, Kampala. Report (1990): 1-48.

Otim-Nape, G. W., J. M. Thresh, and D. Fargette. "Bemisia tabaci and cassava mosaic virus disease in Africa." Bemisia: 1995, taxonomy, biology, damage, control and management (1996).

Otim-Nape, G. W., T. Alicai, and J. M. Thresh. "Changes in the incidence and severity of cassava mosaic virus disease, varietal diversity and cassava production in Uganda." Annals of Applied Biology 138.3 (2001): 313-327.

Owor, B., Legg, J. P., Okao-Okuja, G., Obonyo, R., & Ogenga-Latigo, M. W. (2004). The effect of cassava mosaic geminiviruses on symptom severity, growth and root yield of a cassava mosaic virus disease-susceptible cultivar in Uganda. *Annals of applied biology*, *145*(3), 331-337.

Pellet, D., & El-Sharkawy, M. A. (1993). Cassava varietal response to phosphorus fertilization. I. Yield, biomass and gas exchange. *Field Crops Research*, *35*(1), 1-11.

Pinkerton, M. G., Thompson, S. M., Casuso, N. A., Hodges, A. C., & Leppla, N. C. (2019). Engaging Florida's Youth to Increase Their Knowledge of Invasive Species and Plant Biosecurity. *Journal of Integrated Pest Management*, *10*(1), 1.

Pruthi, H. S., and C. K. Samuel. "Entomological investigations of the leaf curl disease of tobacco in Northern India. V. Biology and population of the whitefly vector, Bemisia tabaci (Genn.) in relation to the incidence of the disease." Indian Journal of Agricultural Science 12 (1942): 37-57.

Queiroz, J. M., & Oliveira, P. S. (2001). Tending ants protect honeydew-producing whiteflies (Homoptera: Aleyrodidae). *Environmental Entomology*, *30*(2), 295-297.

Rogers, D. J., & Appan, S. G. (1973). Manihot and Manihotoides (Euphorbiaceae): A computer assisted study. *Flora neotropica*, *13*.

Rogers, D. J., & Fleming, H. S. (1973). A Monograph of Manihot esculenta: With an Explanation of the Taximetrics Methods Used. *Economic Botany*, *27*(1), 1-113.

Shah, M. M. R., & Liu, T. X. (2013). Feeding experience of Bemisia tabaci (Hemiptera: Aleyrodidae) affects their performance on different host plants. *PLoS One*, *8*(10), e77368.

Steel RGD, Torrie JH, Dickey DA: Principles and procedures of statistics; a biometrical approach. 3rd edition. McGraw-Hill, Boston; 1997.

Stocks, I. C. (2012). Bondar's Nesting Whitefly, Paraleyrodes bondari, a Whitefly (Hemiptera: Aleyrodidae) New to Florida Attacking Ficus and Other Hosts. *Pest Alert*.

Swanson, H. K., Lysy, M., Power, M., Stasko, A. D., Johnson, J. D., & Reist, J. D. (2015). A new probabilistic method for quantifying n-dimensional ecological niches and niche overlap. *Ecology*, *96*(2), 318-324.

Team, R. C., Bivand, R., Carey, V. J., DebRoy, S., Eglen, S., Guha, R., ... & Pfaff, B. (2020). Package 'foreign'.

Vayssieres, J. F., Korie, S., Coulibaly, O., Temple, L., & Boueyi, S. P. (2008). The mango tree in central and northern Benin: cultivar inventory, yield assessment, infested stages and loss due to fruit flies (Diptera Tephritidae). *Fruits*, *63*(6), 335-348.

Vidya, C. V., Sundararaj, R., Dubey, A. K., Bhaskar, H., Chellappan, M., & Henna, M. K. (2019). Invasion and establishment of Bondar's nesting whitefly, Paraleyrodes bondari Peracchi (Hemiptera: Aleyrodidae) in Indian mainland and Andaman and Nicobar Islands. *Entomon*, *44*(2), 149-153.

Von Arx, R., J. U. Baumgaertner, and V. Delucchi. "Developmental biology of Bemisia tabaci(Genn.) (Sternorrhyncha, Aleyrodidae) on cotton at constant temperatures." Mitteilungen der Schweizischen Entomologischen Gesellschaft 56.3 (1983): 389-399.

Wakiso district LG development plan FY 2015/16-2019/20.

Wang, W., Feng, B., Xiao, J., Xia, Z., Zhou, X., Li, P., ... & Peng, M. (2014). Cassava genome from a wild ancestor to cultivated varieties. *Nature communications*, *5*(1), 1-9.

Wool, D., and S. Greenberg. "Esterase activity in whiteflies (Bemisia tabaci) in Israel in relation to insecticide resistance." Entomologia experimentalis et applicata 57.3 (1990): 251-258.

APPENDICES

Appendix 1: Sampling tool

Country		Date	
District		Neighboring cassava fields	
Sub- County		Field size (m2)	
Parish			
Village		Age (months)	
Latitude		Intercrop	
Longitude		Cassava Varieties	
Altitude (m)		Sampled Varieties	
Farmer's name		Researcher(S)	

Plant No.	Adult W/F count		Nymph Count of *P.bondari*	Disease severity	Remarks
	P.bondari	*B. tabaci*		CMD	
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					