COMPARATIVE DIFFERENCES OF WHITEFLY-TRANSMITTED DISEASES BETWEEN LOCAL AND HYBRID BEAN VARIETIES IN KITUI COUNTY, KENYA

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Declaration

I understand that plagiarism is an offense, and I, therefore, declare that this report is my original work and has not been presented to any other institution for any other award.

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A56/KIT/20283/2013

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Dedication

To my husband Paul Mutua, to my children Brian Muimi, Emmanuel Mulwa, Victor Mwendwa, for their support during my study period.

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Abbreviations and acronyms

BC1MV	Bean Chlorotic mottle virus
BCDMV	Bean curly dwarf mosaic virus
BCMV	Bean common mosaic virus
BGMV	Bean golden mosaic virus
BMMV	Bean mild mosaic virus
BPMV	Bean pod mottle virus
BYMV	Bean yellow mosaic virus
CBB	Common bacterial blight
H.B.	Halo blight
IPM	Integrated pest management
YDC	Yeast-extract-dextrose calcium carbonate agar

ABSTRACT

The typical dry bean, *Phaseolus vulgaris,* is the essential food legume for direct human consumption. They play a significant role in food security and nutrition. Despite their nutritional importance, its production growth rates have declined in Kenya due to diseases, insect pests, plant nutritional deficiencies, and drought. Therefore, this study's main objective was to determine whether there are differences in bean varieties' tolerance to whitefly transmitted viral diseases. The study had a survey and laboratory phases. The survey covered wetter midlands of Central Kitui County, where fifty-two farms were repeatedly covered in two bean production sites in two years (2017-2018), in Kyangwinya West Ward and Kitui East Ward. A questionnaire was administered to collect data on bean production acreage, type of cropping system, pest and diseases, pesticide, and fertilizer use by farmers on bean production. Each farms' location was marked using the global positioning system (GPS) device. Rainfall data of the production period was secured from Kenya Agricultural and Livestock Sub-Centre of Ithookwe, centrally placed at 2 Kilometres west of Kitui Town. The Whitefly specimens were collected from the named regions and the specimen preserved in 70% ethanol. Bean disease lesions were noted following the procedure of observation of the bean leaves for disease symptoms. Viral symptoms were recorded based on the data from observation. Fungal identification was done using pathogens on Potato Dextrose Agar (PDA) combined with a drug (streptomycin and neomycin) while bacteria were differentiated through selective media YDC (yeast extract-dextrose-$CaCo_3$). The fungi were grouped using spore characters on PDA, while bacteria were grouped depending on their color on YDC. Bean production acreage and yield levels were subjected to analysis of variance. The highest density of *B. tabaci* was observed in Kyangwithya-West ward at close to 2 whiteflies per field plot of $1m^2$. After laboratory analysis, disease incidence among the varieties showed that improved varieties had a higher incidence of fungal, bacterial, and viral diseases than the local cultivars. Mwezi-Moja had the least disease incidence of 1%, while Rosecoco, B1, and Nyayo, with ≥ 5% of fungal diseases, identified as *Altenaria* and *Phoma* species as common ones on the dead lesions. The bacterial diseases found on the leaves were *Pseudomonas spp,* grouped in the fungal lesions. The local cultivar with the least incidence was Wairimu indicating 1% fungal disease occurrence, mainly being *Altenaria species*. The local variety bearing the highest viral disease was Mwitemia at 3%, of Bean Golden Yellow Mosaic Virus (BGYMV). However, the varieties had a less than 10% incidence of both fungal and viral diseases. There is a need to develop bean genotypes through seed breeding, which are ecologically adaptive to the water-stressed environment to increase food security.

CHAPTER 1

1.0 GENERAL INTRODUCTION

1.1 Bean production

The common dry bean, *Phaseolus vulgaris*, is the most essential food legume for human consumption around the globe (Pachuco 1989; Uebersax 1991). Production occurs in a wide range of cropping systems and environments in most parts of the world (Hofstra and Ormirod 1977; Laurence and Weistein, 1981; Kohut and Lawrence 1983; Adhikari et al., 2015). In Latin America, the leading bean producer and consumer, beans area traditional and very important food for the lower-income people, particularly in Brazil, the Andean Zone, Central America, and some Caribbean countries (Norman 1981; Golay et al., 1986; Harrison 1988; Hardwick 1988; Lating 1994; Letermep and Monoz 2002). However, the world's highest per capita consumption occurs in eastern Africa where beans are seen as the main source of protein. Beans can be prepared for food mixed with bananas, maize, rice and can also be powdered to make flour for porridge, chapati, and Ugali.

According to the Food Agriculture Organization (FAO, 2015), bean production declined from 6.1% to 2.8% due to varied constraints affecting support institutions (Mauyo et al., 2007). In tropical bean production regions, diseases, insect pests, and low soil fertility are the most important production constraints (Zaumeyer and Thomas, 1957; Wang et al., 1985; Stary et al., 1985; Gichangi et al., 2015). Most of the landraces and improved varieties are grown in these areas are susceptible to one or more of these production constraints, preventing the realization of their full yield potential and causing production instability from one year to the next (. More plant pathogens, greater pathogenic variation, and more virulent isolates of these pathogens are found attacking beans in Africa and especially Kenya than in temperate regions (Liebman and Duck 1993). The prevalence and importance of each disease vary considerably with locality, season, year, and cultivar (Letcher et al., 1970. However, some pathogens, such as those that cause anthracnose, angular leaf spot,

The common bacterial blight, rust, and bean common mosaic virus, are widespread and economically important (Zaumeyer and Meiners 1975; Saettler,1978). Usually, one or more of these pathogens cause yield losses in most bean-producing areas of Africa and Kenya in particular (Wallace 1939; Xiamung 1997). Other pathogens are also significant economically but are restricted to growing regions with specific environmental conditions that favor their survival and spread (Xiamung 1997). This group includes bean golden mosaic virus, web blight, and ascochyta blight (van Schounhoven and Voysects 1989). Some are widespread but not economically important such as root rots, and the rest are not widespread and not economically important (Davids *et al*., 1981). Insect pests are very important in Africa and cause considerable damage to production before and after harvest (Bubenzer and Weis, 1994). Some significant pests are restricted to one continent (Vetten and Allen 1983). For example, Bean fly is extremely important in Africa (Wyse *et al*., 1976b; Laurence, 1981). Bean pod weevil is economically important and present only in Kenya and some countries of Africa.Insect pests such as bruchids and leafhoppers are widespread in most tropical bean-producing regions.

In Africa, beans are grown on many different soil types, limiting plant growth, and yields because of nutritional deficiencies or toxicities (Jackson and Colavito, 1976). Edaphic problems have been extensively reported for large bean production areas of Africa and Kenya in particular. In the developing world, small farmers are the principal producers of beans, often as a secondary crop in association with maize (Kulkami 1973; Mussa and Russel, 1977; Leterme and MunÕz, 2002). A high proportion of beans in these developing countries is consumed on the farm and traded only in local markets. Thus, with limited resources and other pressing demands on the administrative capacity of agricultural ministries of many developing countries, the difficulties of collecting accurate data on common beans are immense (Pell, 1976).

Consequently, data for many countries, including developing ones, is cumbersome to collect. In most developing world regions, bean production has deteriorated in the last ten years. In Eastern Africa, the African Great Lakes Region and southern Africa all experienced slower growth in bean production during 1972-74 and from 1982-84 than the previous decade (Chirwa *et al.,* 2007; Birachi *et al.,* 2011). In the present decade, the ever-increasing population has increased demand for beans in all the identified regions. In general, there has been little improvement in yields (Birachi *et al.,* 2011). This is true both for slow-growth regions such as Eastern Africa (Otsula 1994).

1.2 Problem statement

Beans are grown in most parts of Kenya and constitute the most important food legume for more than 42 million people in Kenya. Beans are the third leading source of protein after fish and chicken and are also an important source of calories for many of Kenya's poorest (FAO, 2015). Despite their nutritional importance, their production growth rates have declined in Kenya (Korir et al., 2005). In most low-input systems where most beans are produced, the principal factors responsible for low bean yield and quality losses are diseases, insect pests, plant nutritional deficiencies, and drought (Pachico, 1989).

Most of the small-scale farmers in Kenya have faced many constraints during the production of dry beans. This has led to low yields hence insufficient food supply, especially protein sources. Being an annual crop and a popular legume grown in most Kenyan regions, most food recipes have a special place as a stew and whole-grain production. A focus on pest and disease identification and proper management will improve production levels because beans' pests and diseases pose a major threat in bean production.

Positive correlations have been observed between *B. tabaci* populations, and bean common mosaic virus (BCMV) spread into initially healthy bean plants (Griesler et al., 2002; Karkashian 2011). The size of the whitefly populations has also been positively correlated with virus spread about one month after the invasion, which corresponds to the time necessary for symptom development (Ahmed and Mills, 1985; Galvez and Morales 1989). These examples are, therefore, an indication that disease spread might be facilitated when a high population density of *B. tabaci* feeds on plants containing a high virus and subsequently infects disease-free plants over a large area.

Several species of whitefly *exist, namely, Aleurodic trachelussocialis, T. desvariabilis, Bemisia tabaci, Aleurodicu dispersus,* and *B. afer* being common species present in Africa (Bellotti, 2012). Entomologists have identified approximately 1,500 species of whitefly with *B. tabaci,* being the most common species to which crop losses are attributed to in tropical regions (Opio and Male-Kayiwa, 1994; Makini 1994). It is generally accepted that *B. tabaci* populations are geographically delimited (Frohlich *et al.*, 1999; Brown, 2000; De Barro *et al*., 2000).

According to Mware *et al.* (2009), there is a positive correlation between common mosaic virus incidence and the number of adult whiteflies on cassava, suggesting a possible contribution of the whiteflies to spread bean common mosaic virus on beans. This is also supported by work done in Uganda by Alicia *et al. (*2007).

According to Njoroge et al. (2017), the superabundance of *B. tabaci* seems to enhance the spread of common mosaic virus on cassava. However, the rate of common mosaic virus transmission on beans is low in a controlled environment (Marales 2001; Omomgo et al., 2012) compared to high bean common mosaic virus incidences observed in the field concerning whitefly population than those reported earlier by Alicia *et al*. (2007) thereby calling for further studies to focus on testing of other bean infesting whitefly species for their ability to transmit bean common mosaic virus which are a major threat to bean production in Kenya.

This work, therefore, seeks to come up with the distribution pattern of different Whitefly species in Kitui County and will correlate the density and association of the whiteflies with the spread of viral diseases on beans in local and hybrid varieties in Kitui central sub-county and surroundings and advice farmers on the most appropriate variety to grow.

1.3 Justification

Comparative differences of whitefly transmitted diseases in cassava have been conducted in some parts of Kenya, according to Njoroge *et al.* (2017), but little has been done towards the study of Whitefly species in beans. Such studies in the arid and semi-arid lands (ASALs) of the South-Eastern parts of Kenya have not been adequately carried out. This study will provide useful information to the government, which, through its Vision 2030, hopes to improve food security by improving bean productivity through pests and disease management. The study will benefit the Ministry of agriculture and Ministry of trade-in formulating and evaluating food security strategies as key components in agriculture productivity. It will also benefit agriculture value chain players such as input suppliers, producers, processors, exporters, donors, and other food security sub-sectors' financiers to evaluate its overall performance. This will help them to make decisions for further funding in the agriculture sector. The findings will also provide a useful guide to researchers and scholars who wish to research this area further. It will also help farmers identify the best resistant bean variety to grow for high crop yield.

1.4 General Objective

This study's general objective was to ascertain if there are notable differences in bean varieties' tolerance to whitefly transmitted viral diseases.

1.4.1. Specific objectives

The specific objectives were: -

i. To determine bean varieties grown in Kitui central sub-county
ii. To determine whitefly species diversity in Kitui central sub-county
iii. To compare the yield of diseased and non-diseased genotypes of local landraces and hybrid varieties.

1.5 Hypothesis

i. There is no diversity in bean varieties grown by farmers in Kitui sub-counties.
ii. There is no difference in whitefly species diversity in local landraces and hybrids of beans.
iii. There is no difference in yields of diseased and non-diseased genotypes of local landraces and hybrid varieties.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Major bean production constraints

The main bean production constraints reported are caused by pests and diseases. However, in systems involving complex associations, researchers often claim that farmers' practices are suboptimal is difficult to evaluate objectively because research designs become almost impossibly complex. Too often, assumed priorities reflect prejudice on the scientist's part rather than the real constraints to crop productivity. Indeed, bean production levels in agriculture are balanced, self-supporting tropical agro-ecosystems (Igbozurike, 1971; Janzen, 1973; Vetten and Allen, 1983; Van Schoonhoven and Voysest, 1989; Sietsche et al., 2000; Sastry, 2013; Smith *et al.*, 2015) in which co-evolved crops have achieved an equilibrium, not only with one another and with their environment (Bunting, 1975) but also with their parasites.

The literature on bean diseases in Africa is fragmentary (Omongo *et al.*, 2012). Most major reviews have not dealt extensively with African literature, although Allen (1983) has attempted to address the imbalance. The most important viral pathogen of beans in Africa is the bean common mosaic virus (BCMV). It is reliably identified from central and eastern Africa, where necrotic strains are common and damaging (Kulkarni, 1973; Omunyin, 1979; Schwartz *et al.*, 1982; Mink, 1985; Silbernag *et al.*, 1986; CIAT, 1987; Makini,1994). Peanut stunt virus has been identified recently in beans in Sudan (Ahmed and Mills, 1985), but *cucumoviruses* are not known from beans in East Africa (Bock *et al.*, 1975; Singh, 1991; Thompson, 2011). Similarly, the southern bean mosaic virus (SBMV) has not yet been detected in beans in eastern Africa, although it is known in legumes in western Africa (Lamptey and Hamilton, 1974; Givord, 1981).

Bean golden mosaic virus (BGMV) has not been found, although a closely related virus occurs in Nigeria's lima beans (Williams, 1976; Vetten and Allen, 1983).

Cowpea mild mottle virus, known in various legumes in West Africa, has been found in beans' natural infections in Tanzania (Mink, 1985; Sseruwagi *et al.*, 2005). Alfalfa mosaic virus is recorded in beans in South Africa *(*Neveling, 1956). Both tobacco mosaic virus (Hollings *et al.*, 1981) and bean yellow mosaic virus (BYMV) have been recorded in beans in Kenya, although BYMV is now thought of as eradicated. Peanut mottle virus is also known as *Phaseolus spp.* in East Africa. Among the bacterial diseases, the only one of uncertain status is bacterial wilt caused by *Curt bacterium flaccumfaciens* (syn. Corynebacterium), which is thought to occur in Kenya. The bacterial brown spot incited by *Pseudomonas syringae*van Hallpv. syringae is also known from beans in Kenya and Burundi (Ahmed and Mills, 1985). Both common bacterial blight and halo blight are widespread and important. The major fungal diseases of beans in Africa, as in Latin America, are angular leaf spot, anthracnose, and rust. Ascochyta blight is very damaging in the Great Lakes Region's highlands, and a floury leaf spot caused by *Mycovellosiella phaseoli* (Drummond) Deighton is locally important. Web blight is probably of little importance (unlike in Central America, where it is severe). Certain fungal pathogens have not been reported from Africa, including white leaf spot caused by *Pseudocer cosporella albida*, gray leaf spots (*Cercospora vanderysti* Henn and C. *castellanii*, and the round leaf spot, Chaetoseptoria wellmanii Stevenson. Conversely, scab, caused by *Elsinoe phaseoli* Jenkins, is known from beans only in Africa, although it is a pathogen of lima bean and cowpea in the New World *(*Allen et al., 1989).

There is evidence, in some cases, of substantial diversity among pathogens in Africa. Studies of anthracnose, rust, and angular leaf spot have revealed new variants that do not correspond exactly with races described in the New World (Dixon et al., 2014). Preliminary evidence from studies on *Ascochyta blight* in Africa suggests that the most important causal agent is *Phomaexigua var*. *diversispora* and not *P. exigua* var. *exigu*a Desmazieres, the latter being a synonym of *Ascochyta phaseolorum* Saccardo (Karkashian 2011; Smith et al., 2015).

2.1.1. Bean pests and disease control

Use of pesticides is arguably the most preferred method of controlling bean pests. Although insecticides such as Dimethoate, Endosulfan, Fenitrothion, and Monocrotophos have been highly successful, it has sometimes caused adverse effects, especially in developed countries. For example, insecticides kill pests' natural enemies and encourage the development of resistant strains of economically important pests. In addition, farmers in third world countries may at times lack the insecticides due to their high prices or unavailability in the market. Plant extracts, such as neem, offer a new dimension for future chemical control of insects on beans (Schwartz, 1982; Sastryks, 2013). Sources of resistance to important insect pests must be incorporated into agronomically acceptable cultivars, such as those already resistant to important plant diseases (Sietsche et al., 2000). The use of natural enemies (parasites, predators, and pathogens) as a method of controlling bean pests has not yet been adopted in Africa, even though it is effective (Ssemwangi et al., 2005).

Nevertheless, many pests such as bean aphids are controlled, without human intervention, by their parasites in many bean-growing countries of Africa. It is only recently that exotic aphid parasites, *Aphidius colemani* Viereck and *Aphidius bertrand* Benoit (Singh 1991), were introduced into Burundi to help the indigenous was partly regulating bean aphid populations. The short growing season of beans and fallow periods may hinder the implementation of an effective and deliberate biological control strategy for bean pests in traditional African farming systems (Saettler, 1989). Various cultural practices such as optimal plant populations, appropriate time of planting, species diversity, use of trap crops, crop rotation, intercropping, and removal of crop residues, have shown potential for controlling bean pests (Mattersun et al., 1984). Cultural practices are readily available to the subsistence farmer and, in most cases, do not require extra investment. There are many advantages in associated mixed cropping, such as reduced pest incidence and damage, erosion control, lower economic risk, and crop productivity optimization (Thompson 2011). Although mixed cropping reduces some species' pest population, it must be combined with other crop protection strategies to optimize yields (MMbanga et al., 1986). Literature from many studies in several African countries suggests that large yield increases can be obtained with effective insect control (Nyiira, 1978). Plant damage is more pronounced in dry conditions than in wet. Several control methods have been used for the control of bean fly with varying degrees of success. Cultural practices, such as adjustment of planting time, crop rotation, and associated cropping, can reduce bean-fly populations and damage (Greathead. 1968; Abate, 1996). Earthing-up (hilling) is often recommended as a cultural control practice because the bean plant produces adventitious roots above the damaged stem part and recovers from bean-fly damage. Several insecticides, including dimethoate, endosulfan, monocrotophos, cypermethrin, and pyrethrum, are effective against bean fly (Allen et al., 1989; Chirwa et al. 2007). Xiamung (1997) has demonstrated reduced bean fly damage methods by using neem (*Azadirachta Juss*) extract, an insecticide of plant origin. Many parasites of bean-fly have been reported (Wallace, 1939; Hassan, 1947; Greathead, 1968; Valverde *et al.*, 1982). The development of resistant cultivars offers a promising means for bean-fly control. Varietal resistance to *O. phaseoli* in common beans has been reported from Mauritius, Australia, and Taiwan (David et al., 1981; Dixon et al., 2014). In Ethiopia, Abate (1996) screened about 200 bean accessions under a moderate bean-fly attack. Resistant bean lines have also been found in Malawi (Birachi et al., 2011).

Both adults and nymphs of whitefly suck sap from leaves. When infestation is severe, the upper surface of leaves becomes mottled with light yellowish spots. However, direct feeding damage is minor compared with the possible indirect effect of virus transmission. The species *B. tabaci* is the vector of the bean golden mosaic virus (BGMV) (Opio and Kaywa, 1994). However, this virus has not yet been identified on beans in Africa (Navas-Castilo et al., 2011). The species *B. tabaci* also transmits cowpea mild mottle virus (CPMMV), long known in various African hosts, including peanuts (Lapidt et al., 2014). CPMMV has recently been found in beans in Tanzania (Fargette 1994).

CHAPTER 3

3.0. MATERIALS AND METHODS

3.1 Farm survey on production

The survey covered wetter midlands of Central Kitui County in 2017 and 2018. Twenty-two farms were covered in two bean production sites of Kyangwithya West Ward and Kitui East Ward in 2018 (Fig. 1). Earlier in 2017, 30 farms had been sampled in the same region. Kyangwithya is 5 Km west of Kitui Town, while Kitui East ward is about 6 Km on the eastern side. Kitui is 180 Kilometres east of Nairobi City of Kenya. Each farmer was interviewed through a questionnaire on bean production. Later on, during the harvest, the selected plots were visited to get data of the crop harvest. The global positioning system (GPS) was used to locate each farm's coordinates within the study sites. Rainfall data of the production period was obtained from Kenya Agricultural and Livestock Research Organization Sub-Centre at Ithookwe, which is centrally placed at 2 Kilometres west of Kitui Town.

Figure 1: Whitefly survey sites during the production bean seasons of 2017-2018

3.2 Whitefly specimen collections

In each of the study farms, whitefly specimens found on bean leaves were collected using either an aspirator or by handpicking with ethanol-wet hair brushes (size 000) and placed vials containing 70% alcohol where a maximum of 10 individual adults was preserved in each vial. Adjacent weed plants were noted for relatedness to bean plant Family Fabaceae. A quadrat of 1 m^2 was used to mark the net sample area in each random sample plot per farm. The quadrat sampling was repeated five times per farm plot.

3.3 Laboratory specimen identification

Whitefly specimens were collected from each locality and preserved in vials containing 70% ethanol were identified using the character states by Martin (1987; 2004) describes specimens with upper and lower compound eyes (Ocelli structures) were regarded as *Trialeuroides vaporariorum*, while those connected with the ocelli body into one block with single constriction gap were identified as *Bemisia tabaci*. A more detailed scrutiny was done on the whitefly's hind leg on the mesototibia part, where for *B. tabaci*, it was 2-3 comb brushes, and *T. vaporariorum* was 4-7 metatibial combs (Martin, 2004). The analysed specimen still on the glass slides were then stored for future reference at the Kenya Agricultural and Livestock Research Organization laboratory.

3.4 Laboratory disease identification

Bean disease lesions were identified by using the visual symptoms on diseased bean leaves. Viral symptoms were confirmed, through observation, as those resulting from bean diseases caused by viruses in bean literature reference. Fungal isolations were carried out; this involved growing the pathogens on Potato Dextrose Agar (PDA) amended with a drug (streptomycin and neomycin) while bacteria were differentiated through selective media YDC (yeast extract-dextrose-$CaCo_3$) YDC. The fungi were grouped using spore characters on PDA, while bacteria were grouped depending on their color on YDC.

3.5 Statistical analyses

The farmer cultivar preference, whitefly density, and disease incidence were presented in the form of percentages. A graph drawn using Microsoft Excel (2013) was used to represent temperature and rainfall amounts for the two production months (April and May 2017 and similarly in 2018). The bean production acreage was also analyzed by computing for the variance of the production using Fisher's Least Significance Difference (LSD) Test at $P \leq 0.05$), using SAS software on General Linear Model (GLM) PROC.

CHAPTER 4

4.0 RESULTS

4.1.1. Farmer cultivar preference

Out of the twenty-two farms sampled, 23% were men, and 77% were women producers. This implies that women favor growing of beans. The highest cultivar preference was a tie of KAT Bean 1 (B1) of improved variety category and Mwitemania, a local cultivar at 24% as each category's total (Table 4.1). This meant that by combining both cultivars B1 and Mwitemania, they accounted for 48% of bean production in the two wards. The least preferred cultivar was Wairimu grown in Kitui East only. Other local cultivars appeared as an isolated preference by a few farmers in production areas, as indicated in Table 4:1.

Table 4 1. **Farmers' bean Cultivar preference Changwithya and Kitui Eat Wards of Kitui County**

Ward	**Farmer cultivar preference (%)**						
	Improved varieties				Local cultivars		
	Rosecoco	B1	Nyayo	Mwezi-Moja	Wairimu	Kamwithokya	Mwitemania
Changwithya	13	11	12	8	0	3	16
Kitui East	3	13	5	0	3	5	8
Total (%)	16	24	17	8	3	8	24

The rainfall reliability and pattern were questionable in 2017 and but an improved was recorded in 2018. A daily mean rainfall amount of 7.99 ± 2.83mm was recorded for the two production periods. It was noted that May was cooler than April during the production periods. The temperature range in April was 21 ± 2 °C while May was 20 ± 3 °C. An improvement in the amount of rainfall was registered in the subsequent short rain (S.R.) period of October-December 2017 to January-February 2018. The mean daily rainfall of 12.2 ± 9.3mm was recorded for the production period. The temperature range in November was 23.1 ± 2, and in January 2018 was 23.5 ± 2 °C.

There was no significant altitude difference among the two ward locations. Mean bean production acreage during the two seasons was notable in Kitui East than Changwithya at 1.6 and 0.3 /ha, respectively. Bean production system showed farmers preferred maize for intercropping with beans. Passion fruit and cassava were other intercrop options for farmers in Kitui East. Only a single farmer reported to have used mineral fertilizer for bean production in Kitui East. Manure was a common input for all the other farmers.

Table 4 2. **Plot acreage, altitude, intercrops systems of bean production in Changwithya west and Kitui East wards of Kitui County**

Ward	**Altitude (m)**	**Acreage (ha)**	**Intercrop system**
Changwithya West	1166.3^{A}	0.3^{B}	Maize, cowpea, cassava
Kitui East	1024.0^{A}	1.6^{A}	Maize, pigeon pea, passion fruit
SE	231.3	2.4	
LSD	219.8	2.4	

Indicated similar superscript letters denote no parameter variable significant difference (Fisher's Least Significant Difference Test, df = 1, 10) at 5% level.

4.1.2. Whitefly species diversity

Only two Whitefly species were discovered in the laboratory analysis namely; *T.vaporariorum* and *B. tabaci*. The *T. vaporariorum* was noted in Changwithya Ward while Kitui East Ward had both species in only one field plot with a 4.5% incidence (Fig.4.2). The *B. tabaci* species was dominant in the field plots in Changwithya West Ward. Almost every field plot selected for the study had at least 3 whiteflies per field plot of $1m^2$. No other major insect pest was found on bean plots except several species of aphids on individual plants.

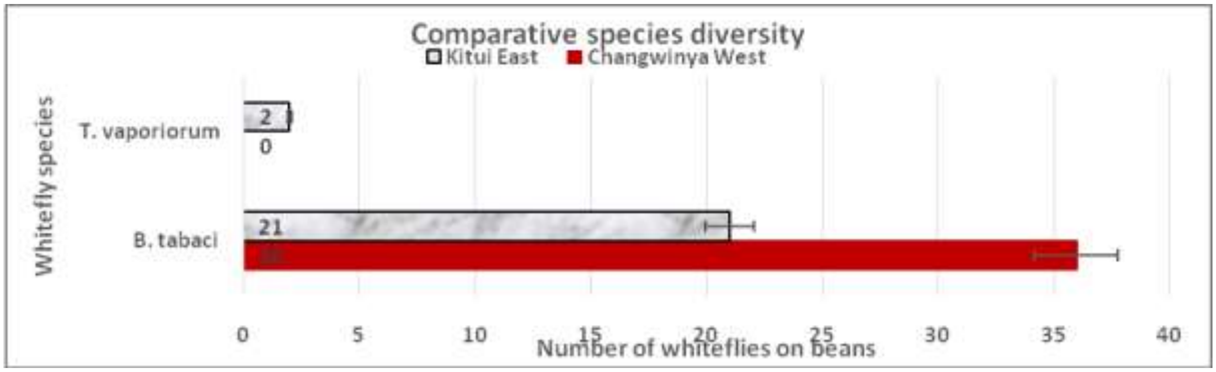


Figure 4.2: The Comparison of whitefly species diversity and abundance in Kyangwithya West and Kitui East Wards

4.1.3. Disease identity

Field visual estimates of fungal diseases were 20 and 28% for Kyangwithya West and Kitui East, respectively (Fig.4.3). Likewise, viral disease incidences were 17 and 8% for Kyangwithya and Kitui East, respectively. These were symptomatic lesions at field observations on the plant leaves evident, and the participating farmers could easily recognize the disease symptoms. The symptoms and perceived loss could not induce the disease incidence's impact on yield loss.

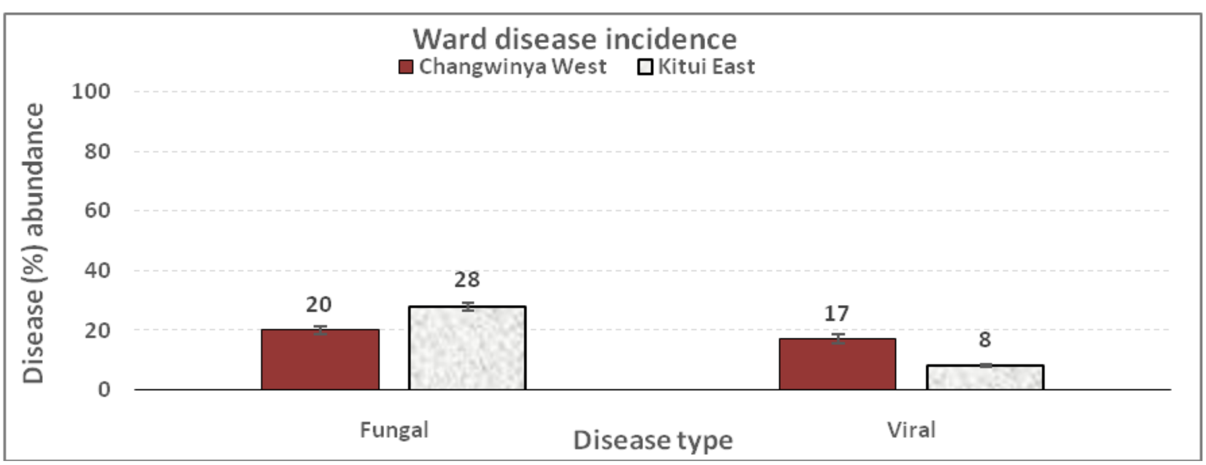
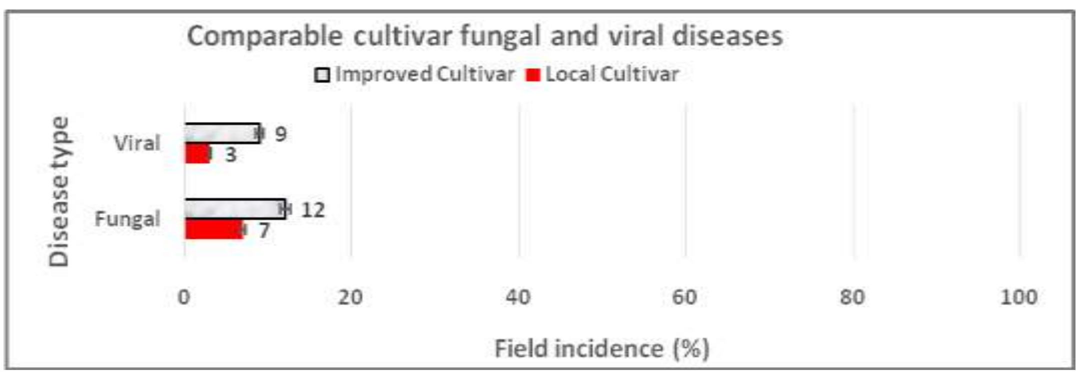


Figure 4.3: Visual estimation of fungal and viral diseases in Kyangwithya West and Kitui East wards of varied whitefly density infestations

The analysis from the laboratory revealed that improved bean varieties were prone to disease infection than the local bean varieties. In the analysis in (Fig.4); Mwezi-Moja had the least disease incidence of 1%, while Rosecoco, B1, and Nyayo, with ≥ 5% of fungal diseases, identified as *Altenaria* and *Phoma* species were found on the dead leaves. The fungal lesions indicated bacterial diseases that are Pseudomonas spp grouped. The local cultivar with the least incidence was Wairimu indicating 1% fungal disease occurrence, mainly being *Altenaria* species. The local variety bearing the highest viral disease was Mwitemia at 3%, of Bean Golden Yellow Mosaic Virus (BGYMV). There was no case relating to a single plot having both fungal and viral diseases.

A



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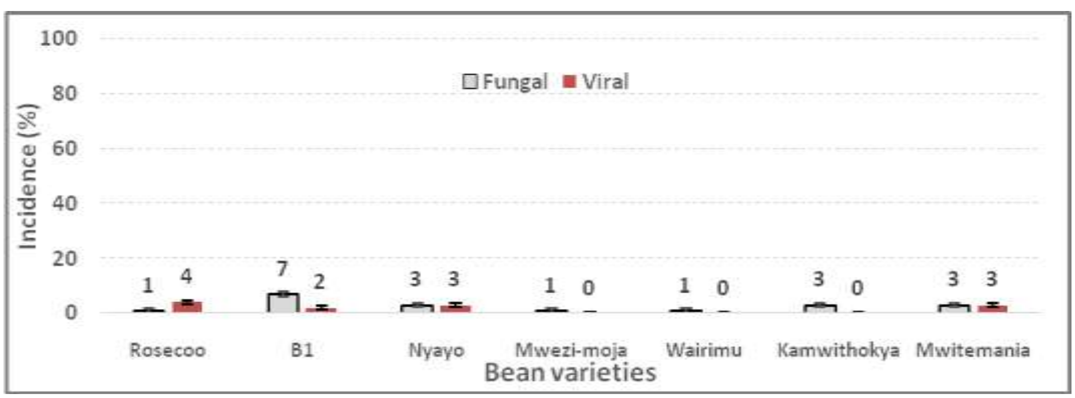
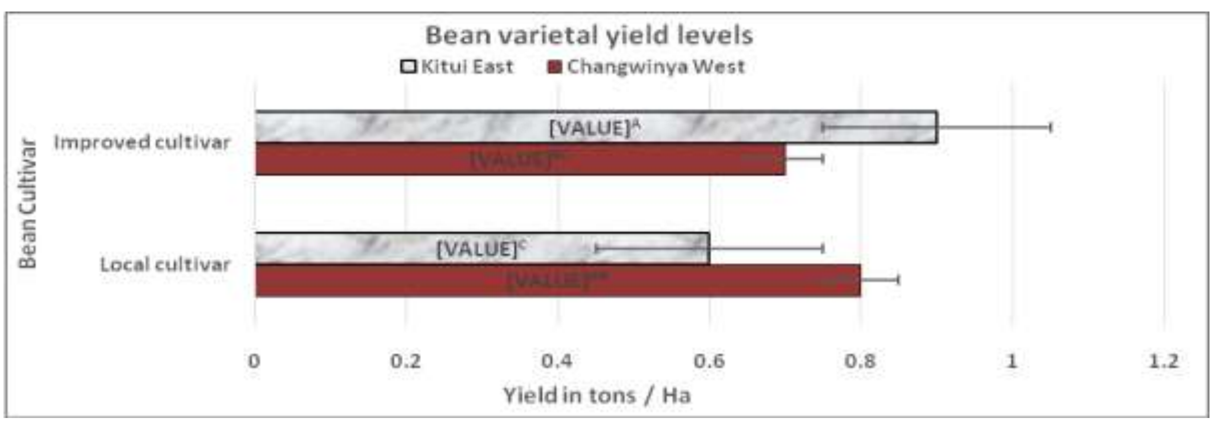


C

Figure 4.4, A&B: Incidences of fungal and bacterial diseases on local landraces and hybrid varieties in Kitui County. C: Procedure for diseased leaves collection and whitefly identification in the laboratory.

Varietal yield difference was significantly ($p < 0.05$) greater in Kyangwithya West, with the improved varieties being at 0.9 tons/ha, followed by local cultivars at 0.8 tons /ha in the same ward (Fig.5). The least yield occurred in Kitui East of the local cultivars at 0.6 tons /ha. Disease incidence showed little influence on varieties where Rosecoco, B1, Mwezi-Moja, and Nyayo (improved category) had the highest disease lesions, leading with the highest yield (0.9 tons /ha) in Kitui East, comparable to 0.7 tons /ha in Kyangwithya West.



Indicated similar superscript letters denote no significant yield difference (Fisher's Least Significant Difference Test, df= 1, 10) at 5% level.
Figure 4.5: Local and Improved bean cultivar yield in Kyangwithya west and Kitui East wards.

CHAPTER 5

5.0 DISCUSSION

The present study results confirmed that the species of whitefly affecting the bean crop in theArid and Semi-Arid lands of Kitui were *B. Tabaci.* The viral vector recorded the highest incidences in Kyangwithya Ward, which correlated to the bean golden mosaic virus (BGMV) from visual identification. Various pests and diseases have been reported on bean crops (Lating *et al*., 1984; Giesler *et al.*, 2002; Navas-Castillo *et al.,* 2011). No relationship between the present and analyzed data and the data from other researchers. Data of wild genotypes, and Fabae types of plant family were not confirmed. In addition, the exact disease effects revealed on the laboratory analysis was low at not greater than 10% on all varieties, as indicated by the analysis. The greatest yields of dry beans were from hybrid varieties at 0.9 t ha-^{1} in Kitui East, and also in Kyangwithya West with 0.7 t ha^{-1}. The local and improved varieties had no major difference in the recorded yields as the former scored 0.6 and 0.8 t ha-^{1} at Kitui East and Kyangwithya Wards, respectively. It appeared that low and unreliable, poor distributed rainfall lead low yields in comparison to effect of diseases and minimized major pest insects. Based on the observation, most farmers were not using mineral fertilizers, hence unreliable rainfall distribution could be suggested as one of the factors leading to low bean production in terms of farmer's input and environmental effects (Birachi *et al*., 2011).

The number of women participating in beans production was higher than their counterparts and majority of them were growing improved varieties, Rosecoco, Nyayo, and KAT B1 at 24, 17, and 16% variety preference, respectively. Of the local varieties, Mwitemania was the most preserved at 24% from the two sites. In the regions, farmers prefer to grow beans based on the price they fetch in the market ,and other attributes like the seed's fast cookability and color, among other attributes (Letcher *et al.,* 1970; Hardwick, 1988; Chirwa *et al.,* 2007).

Women do engage in trading activities involving beans, and this explains why even in a marginal area like Kitui County the crop production is popular. In an average household, land under beans was 0.6 ha in Kitui East and 0.3 ha in Kyangwithya ward. Maize is preferred as the bean intercrop by most farmers in eastern Kenya. However, small-scale farmers prefer growing beans together with maize compared to pure stands. This is due to the higher yield value from inter-cropping (Norman, 1981; Galvez and Morales,1989; Karkashian, 2011). The following advantage of increased maize production yield even when no fertilizer was used as a result of improved fertility of the by the legumes (Hoftra Ormrod, 1977; Kohut and Laurence, 1983; Opio and Male-Kayiwa, 1994; Korir *et al.*, 2005). This technique is mostly used by communities in Eastern Kenya where ploughing by oxen is a norm to avoid delayed production of crops.

CHAPTER 6

6.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The results indicated that the diseases caused by Fungi and viruses were more on Hybrid beans than the local landraces. The main notable viral disease was (BGYMV). This would however need sampling on wild plant species and pinpoint the source of wild inoculum. Breeding programs could benefit from sourcing genetic local materials that resist diseases.

5.2 Recommendations

(i) Based on this study's findings, bean yields differ significantly due to rainfall availability rather than pest infestation, so there is a need to plant varieties that adapt well in the arid conditions

(ii). There is a need to breed bean genotypes through seed breeding, which are ecologically adaptive to the water-stressed environment to enhance yield and increase food security.

(iii). There is a need for a study to analyze wild bean species of bean family to identify sources of resistance /tolerance to bean pests.

(iv). Suppression of the whitefly populations is necessary to manage viral diseases transmitted by the pest.

REFERENCES

Abate, T. & Ampofo, J.K.O. (1996). Insect pests of common bean in Africa: Their ecology and management. *Annual Rep. Entomology*, 41: 45-75.

Adhikari, U., Nejadhashemi, A.P., & Woznicki, S.A. (2015). Climate change and eastern Africa: a review of the impact on major crops. *Food and Energy Security*, *4*(2), 110-132.

Ahmed, A.H. & Mills, P.R. (1985). Identification of peanut stunt virus in Sudan. *Plant disease*, 69(2), 173-174.

Allen, D.J., Dessert, M., Trutmann, P., & Voss, J. (1989). Common beans in Africa and their constraints. *Bean production problems in the tropics. CIAT, Cali, Colombia*, 9-31.

Birachi, E.A., Ochieng J., Wozemba D., Ruraduma C., Niyuhire M. C., & Ochieng D. (2011). Factors influencing smallholder farmers' bean production and supply to market in Burundi. *African Crop Science Journal*, 19 (4): 335-342.

Chirwa, R.M., Aggarwal vas D., Phiri M.A., & Mwenda R.A. (2007). Experiences in implementing the bean seed strategy in Malawi. *Journal of Sustainable Agriculture*, 29(27): 43-69.

David, H., Nelson, N., & Gepstein, S. (1981). The influence of soil moisture on macroscopic sulfur dioxide injury to pinto bean foliage. *Phytopathology*, 71(1 1): 1208-1212.

Dixon, J. L., Stringer, L.C., & Challinor, A.J. (2014). Farming system evolution and adaptive capacity: insights for adaptive support. *Resources*, 3:182-214. doi:10.3390/resources3010182.

FAO. (2015). Food Agriculture Organization. Statistics available at www.fao.org/news/archive/news-by-date/2015/en

Fargette, D., Jeger, M., Fauquet, C., & Fishpool, L.D. C. (1994). Analysis of temporal disease progress of African cassava mosaic virus. *Phytopathology*, *84*(1), 91-98.

Galvez, G. E., & Morales, F. J. (1989). Whitefly-transmitted viruses. *Bean Production Problems in the Tropics*, 379-408.

Gichangi, E.M., Gatheru, M., Njiru, E.N., Mungube, E.O., Wambua, J.M. & Wamuongo, J.W. (2015). Assessment of climate variability and change in semi-arid Eastern Kenya. *Climatic Change*, 130, 287–297. [CrossRef] [PubMed].

Giesler, L.J., Ghabrial, S.A., Hunt, T.E. & Hill, J.H. (2002). Bean pod mottle virus: a threat to U.S. soybean production. *Plant Disease*, *86*(12), 1280-1289.

Golay, A., Coulston, A.M., Hollenbeck, C.B., Kaiser, L.L., Würsch, P. and Reaven, G.M. (1986). Comparison of metabolic effects of white beans processed into two different physical forms. *Diabetes Care*, *9*(3), 260-266.

Greathead, D. J. (1968). A study in East Africa of the bean flies (Dipt., Agromyzidae) affecting *Phaseolus vulgaris* and of their natural enemies, with the description of a new species of MelanagromyzaHend. *Bulletin of Entomological Research*, *59*(3), 541-561.

Hardwick, R.C. (1988). Review of recent research on navy beans (*Phaseolus vulgaris*) in the United Kingdom. *Annals of Applied Biology*, *113*(1), 205-227.

Harrison, B. D., Muniyappa, V., Swanson, M. M., Roberts, I. M. & Robinson, D. J. (1991). Recognition and differentiation of seven whitefly- transmitted geminiviruses from India and their relationships to African cassava mosaic and Thailand mung bean yellow mosaic viruses. *Annals of Applied Biology*, *118*(2), 299-308.

Harrison, J.G. (1988). The biology of Botrytis spp. on Vicia beans and chocolate spot disease- a review. *Plant Pathology*, *37*(2), 168-201.

Hofstra, G. & Ormrod, D.P. (1977). Ozone and sulphur dioxide interaction in white bean and soybean. *Canadian Journal of Plant Science*, *57*(4), 1193-1198.

Karkashian, J. (2011). Begomoviruses associated with bean golden mosaic disease in Nicaragua. *Journal of Phytopathology,* 95(8): 901-906.

Kohut, R. & Laurence, J.A. (1983). Yield response of red kidney bean *Phaseolus vulgaris* incremental ozone concentrations in the field. *Environmental Pollution Series A, Ecological and Biological*, *32*(3), 233-240.

Korir, M. K., Odhiambo, M.O., Iruria, D.M., Kipsat, M.J., & Serem, A.K. (2005). Bean varietal preference in East African markets and its implications for breeding. *African Crop Science Conference Proceedings,* 7:803-805.

Kulkarni, H.Y. (1973). Notes on East African plant virus diseases: 4. Bean Common Mosaic Virus. *East African Agricultural and Forestry Journal*, *39*(1), 72-76.

Lapidot, M., Legg, J. P., Wintermantel, W.M., & Polston, J.E. (2014). Management of whitefly-transmitted viruses in open-field production systems. In: *Advances in virus research*, 90: 147-206.

Lating, D.R., Jones, P.G., & Davis, H.C. (1994). Common bean (*Phaseolus vulgaris* L.): The physiology of tropical field crops. In: Goldsmith P.R. and Fisher N.M. (eds.). John Wiley, New York, U.S.A., 305-353.

Laurence, J.A., & Weinstein, L.H. (1981). Effects of air pollutants on plant productivity. *Annual Review of Phytopathology*, *19*(1), 257-271

Letcher, R.M., Widdowson, D.A., Deverall, B.J., & Mansfield, J.W. (1970). Identification and activity of wyerone acid as a phytoalexin in broad bean (Viciafaba) after infection by Botrytis.*Phytochemistry*, *9*(2), 249-252.

Leterme, P., & MunÕz L.C. (2002). Factors influencing pulse consumption in Latin America. *British Journal of Nutrition*, 88(3): 251-254.

Liebman, M., & Dyck, E. (1993). Crop rotation and intercropping strategies for weed management. *Ecological Applications*, *3*(1), 92-122.

Makini, F.W. (1994). Bean production and constraints with emphasis on diseases in Kenya. In: Danial D.L. (ed). Proceedings for Regional Workshop for eastern, central, and southern Africa, Nairobi, Kenya.2-6th October 1994. Ministry for Dev. Cop. (DGIS). Netherlands, pp 104-109.

Martin, J.H. (2004). Whiteflies of Belize (Hemiptera: Aleyrodidae). Part 1: Introduction and account of the Sub-Family Aurodidae Quintance and Baker. Zootaxa2004, 681, 1-119.

Martin, J.M. (1987). An identification guide to common whitefly pest species of the World (Homoptera: Aleyrodidae). *Tropical Pest Management*, 33, 298-322.

Martin, G.B., & Adams, M.W. (1987). Landraces of *Phaseolus vulgaris* (Fabaceae) in northern Malawi. II. Generation and maintenance of variability. *Economic Botany*, *41*(2), 204-206

Matteson, P.C., Altieri, M.A., & Gagné, W.C. (1984). Modification of small farmer practices for better pest management. *Annual Review of Entomology*, *29*(1), 383-402.

Mauyo, L.W. Okalebo, J.R., Kirby, R.A., Buruchara, R., Ugen M., & Musebe, R.O. (2007). Legal and institutional constraints to Kenya –Uganda cross-border bean marketing. *African Journal of Agricultural Research*, 2(11):518-582.

Mmbaga, M.T., Steadman, J.R., & Stavely, J.R. (1986). The use of host resistance in disease management of rust in common bean. *Integrated pest management reviews*, *1*(4), 191-200.

Morales, F.J. (2001). Conventional breeding for resistance to *Bemisia tabaci*-transmitted geminiviruses. *Crop Protection*, *20*(9), 825-834.

Navas-Castillo, J., Fiallo-Olive, E., & Sanchez-Campos, S. (2011). Emerging virus diseases transmitted by whiteflies. Annu. Rev. *Phytopathol*. 2011, 49, 219–248.

Njoroge, M. K., Mutisya, D. L., Miano, D. W., &Kilalo, D. C. (2017). Whitefly species efficiency in transmitting cassava mosaic and brown streak virus diseases.*Cogent Biology*, *3*(1), 1311499.

Norman, M. J. T. (1981). A role for legumes in tropical agriculture. In *Graham, Peter H.; Harris, Susan C.(eds.). Biological nitrogen fixation technology for tropical agriculture: Papers presented at a workshop held at CIAT, March 9-13, 1981.*

Nyiira, Z. M. (1978). Pests of grain legumes and their control in Uganda. *Pests of grain legumes and their control in Uganda.*, 117-121.

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

Opio, F., & Male-Kayiwa, S. (1994). The status of bean breeding in Uganda. On: Breeding for disease-resistant with emphasis on durability. Proceedings of Regional workshop for eastern, central and southern Africa: 2nd -6th Oct. 1994, Nairobi Kenya. In: Danial D.L. (ed). Ministry for Development Cooperation (DGIS)-Netherlands, pp110-113.

Otsyula R.M. (1994). The status of bean production and research in Kenya. Breeding for disease resistance with emphasis on durability. In: Danial D.L. (ed). Proceedings for Regional Workshop for eastern, central, and southern Africa, Nairobi, Kenya.2-6th October 1994. Ministry for Dev. Cop. (DGIS). Netherlands, pp 114-119.

Pachico, D. (1989). Trends in World common bean production. *Bean Production Problems in the Tropics*, 10: 1-12.

Saettler, A.W. (1989). Common bacterial blight. *Bean Production Problems in the Tropics*, 2: 261-283.

Sastry, K.S. (2013). Methods of combating seed-transmitted virus diseases. In: Seed-borne plant virus diseases (pp. 185-284). Springer, India.

Schwartz, H.F., Corrales, M.P., & Singh, S.P. (1982). New sources of resistance to anthracnose and angular leaf spot of beans (*Phaseolus vulgaris* L.). *Euphytica*, *31*(3), 741-754.

Sietsche, S., Borém, A., Carvalho, G.A., Rocha, R.C., Paula, T.J., Barros, E.D., & Moreira, M. A. (2000). RAPD and SCAR markers linked to a gene conferring resistance to angular leaf spot in common bean. *Journal of Phytopathology*, 148(2), 117-121.

Singh, S.P. (1991). Breeding for seed yield. On: Common beans. Research for Crop Improvement. In: van Schoonhoven A. and Voysest O. (eds.) CAB Internacional in association with Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia, 383-429.

Smith, H.A., Seijo, E.T., Vallad, E.G., Peres, A.N., & Druffel, L.K. (2015). Evaluating Weeds as Hosts of Tomato yellow leaf curl virus. *Environmental Entomology*, 44: 1101–1107

Sseruwagi, P., Legg, J.P., Maruthi, M.N., Colvin, J., Rey, M.E. C., & Brown, J.K. (2005). Genetic diversity of *Bemisia tabaci* (Gennadius)(Hemiptera: Aleyrodidae) populations and presence of the B biotype and a non- B biotype that can induce silver leaf symptoms in squash in Uganda. *Annals of applied biology*, *147*(3), 253-265.

Starý, P., Remaudiere, G. and Autrique, P. (1985). New and little-known species of aphid parasitoids from Burundi (Hymenoptera, Aphidiidae). In *Annales de la Sociétéentomologique de France*, 21 (2), 133-140).

Thompson, W.M.O. (2011). The whitefly, *Bemisia tabaci* (Homoptera: Aleyrodidae) Interaction with Geminivirus-Infected Host Plants; Springer: Houten, The Netherlands.

Uebersax, M.A., & Occena, L.G. (1991). Composition and nutritive value of dry edible beans: commercial and world food relief application. Michigan Dry Bean Digest, 15 (5):3-12.

Valverde, R.A., & Fulton, J.P. (1982). Characterization and variability of strains of southern bean mosaic virus. *Phytopathology*, *72*, 1265-1268.

Van Schoonhoven, A., & Voysest, O. (1989). Common beans in Latin America and their constraints. On: Bean production in the Tropics; 2nd Edition. Schwartz H.P., & Postor-Corrales M.A. (eds.) - Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia, pp-33-59.

Vetten, H.J., & Allen, D. J. (1983). Effects of environment and host on vector biology and incidence of two whitefly- spread diseases of legumes in Nigeria. *Annals of Applied Biology*, *102*(2): 219-227.

Wallace, G.B. (1939). French bean diseases and bean fly in East Africa. *The East African Agricultural Journal*, *5*(3), 170-175.

Wang, W.Y., Mink, G.I., & Silbernagel, M.J. (1985). The use of enzyme-linked immunoblot assay (eiba) to detect bean common mosaic-virus in individual bean-seeds. *Phytopathology*, 75: (11): 1352-1352.

Xiaomong, W. (1997). Germplasm resources, production, and main biotic problems of dry bean (*Phaseolus vulgaris* L.) in China. Proceedings of Seminar by Centro Internacional de Agricultura Tropical (CIAT); 13th June 1997, Cali Colombia, pp 13-16.

Zaumeyer, W.J., & Meiners, J.P. (1975). Disease resistance in beans. *Annual Review of Phytopathology*, 13(1), 313-334.

APPENDICES

5.3 Appendix 1. Bean whitefly survey data collection form

Date……………………….

Kitui Ward Name…………………

Farmer Name: ……………………. Sex……… GPS reading:

Bean cultivars

No.	Bean variety	Local	Improved	unknown	Other
1					
2					
3					
4					
5					
6					
7					

Land use:

How much is your farm under bean cultivation?

Local variety…………………. acres

Improved variety……………. acres

3.0 BEAN CROPPING TYPE

3.1 Do you grow cassava crops, pure or intercropped?

Pure………………….

Maize intercrop…….

Cowpea intercrop….

Sorghum intercrop….

Other (Specify)………

4.0 FERTILIZER / MANURE USE

4.1 What type of fertilizer do you apply to bean crop?

Type of fertilizer / manure / pulp / foliar	Month	Rates
A)		
B)		
C)		
D)		
E)		
F)		

5.0 DISEASES AND PESTS CONTROL ON BEAN

5.1 Diseases Control

5.1.1 Do you experience any disease problems?

( ) YES

( ) NO

If yes, which ones?

(a)…………….

(b)………….

(C)………….

5.1.2 List down any pesticide (fungicide) you use to control any of the diseases

Pesticide (fungicide) Type Applied	Months	Rates
1)		
2)		
3)		
4)		
5)		

5.2 PEST CONTROL

5.2.1 Do you experience any pest problem on bean crop?

( ) YES

( ) NO

If yes, which ones;

(a)……………….

(b)………………

(c)……………….

(d)……………….

5.2.2 Do you apply insecticides (any pesticides) to control any of the pests?

( ) YES

( ) NO

If yes, which insecticides do you apply?

Insecticide	Month	Rates
1)		
2)		
3)		
4)		
5)		

5.2.3 Apart from insecticide (pesticide), which control method do you apply?

Method	Insect pest controlled	Comment on results
1)		
2)		
3)		
4)		

6. 0 WEED CONTROL

6.1 Do you experience any weed problems in your field?

( ) YES

( ) NO

If yes, which ones;

1)…………………………….

2)………………………………

3)…………………………….

4)………………………………

6.2 Do you apply herbicides to control weeds in the field?

( ) YES

( ) NO

If yes, which herbicides do you apply?

Herbicide	Month(s)	Rate
1)		
2)		
3)		
4)		

5.4 Appendix II. Pest score-sheet per plant on 10 top leaves BYMV and BCMV

Farmer 5 x 5m plot

Site: ………………………………… Date: ……………………….

Plant No.	No. whiteflies	BYMC disease (%)	BCMV diseases (%)	Status: (%) field incidence	Presence of natural enemies	Other pest 1 No/ leaf	Other pest 2 No/ Leaf
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
ŷ± sd							
Lsd (0.05)							