ASSESSMENT OF THE RELATIVE IMPORTANCE OF TOMATO (*Lycopersicon esculentum* Mill) PESTS IN MOROGORO TANZANIA

BY

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ABSTRACT

A study was conducted to investigate tomato pests of relative importance in farmers' fields and the effects of management techniques on pests and yields. Biological monitoring of tomato pests was conducted in Morogoro region, at Kipera and Mlali villages tomato growers' fields in Mvomero district from August to November 2006 and on-station field experiment at Sokoine University of Agriculture Horticulture unit during October 2006 to February 2007. Randomized complete block design (RCBD) was used in farmers' fields. The treatments were tomato management practices by farmers while five sampling areas were replications. At On-station field experiment, RCBD in spilt plot with five replications was used. Two determinate tomato varieties (CALJ and Tanya) were main factors and seven tomato management techniques including fertilizer, mulching, grower standard, IPM, check, intercrop with cabbage and spider plants, respectively, formed the sub factors. Leaf miner, septoria leaf spot and nutsedges were ranked as major pests for tomato production in the two villages. Farmers' fields survey indicated that, 70% of farmers practiced monocropping and 80% depended on purchased seeds. On agrochemical use, farmers applied fungicides and insecticides 5 - 8 times per season. Among management techniques, mulching and IPM were effective in suppressing sedges population by 98.9% and 99.6%, respectively. The study also showed significantly reduced insect pest populations in Grower standard and IPM. Furthermore, the study indicated that, spider plants attracted more of both insect pests and beneficial insects compared to tomato monocrop. The study showed that mulching resulted in five times cumulative yields compared to control. Highest number of damaged fruits was due to sunny scotch in farmers' fields and mulching treatments. The study suggests that mulching and IPM could be used to suppress tomato pests and spider plants could be incorporated in a tomato cropping systems to increase beneficial insects' abundance and diversity.

DECLARATION

I, Julita Edward Muro Bulali, hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my original work and that it has never been submitted for a degree in any other University.

13/10/2008

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The above declaration is confirmed

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ABBREVIATIONS

%	Percent
^0C	Degree Celsius
a.i	active ingredient
ANOVA	Analysis of variance
AVRDC	Asian Vegetable Research and Development Center
BA	Basal application
BER	Blossom end rot
BWM	Bollworm
CABI	Commonwealth Bureau of Agriculture International
CHK	Check
CM	Clean marketable
cm	Centimeter
CRSP	Collaborative Research Support Program
CTAHR	College of Tropical Agriculture and Human resource
Cv	Cultivar
CY	Cumulative yield
DAT	Days after transplanting
DD	disease damage
DMRT	Duncan Multiple Range Test
E	East
EB	Early blight
EC	Emulsified concentrate
Fif	Figure
FR	Fruit rot
FTL	Fertilizer

g	gram
GC	Growth crack
GRS	Grower standard
ha	Hectare
HESLB	Higher education students' loan board
ID	Insect damage
IPM	Integrated pest management
K	Potassium
K1 - K5	Kipera fields
Kg	Kilogram
LB	Late blight
lts	Litres
m	meter
M	Mancozeb
M1 – M5	Mlali fields
max	Maximum
min	Minimum
MLH	Mulch
mm	Millimeter
MOA	Ministry of Agriculture
MSU	Maseno University
N	Nitrogen
no	Number
P	Phosphorus
P	Probability
P_2O_5	Phosphorus peroxide
PD	Physiologically damage

PhD	Doctor of Philosophy
RCBD	Randomized Complete Block Design
RH	Relative humidity
SAR	Systemic acquired resistant
S	South
SE	Standard error
SLS	Septoria leaf spot
SM	Spider plant monocrop
Spp	Species
SS	Sunny scotch
STB	Stinkbug
SUA	Sokoine University of Agriculture
TCI	Tomato-cabbage intercrops
TIDF	Total insect damaged fruits
TM	Trade mark
ToM	Tomato monocrop,
TP	Top dressing
TPDF	Total physiologically damaged fruits
TSI	Tomato-spider plants intercrop
TYLCTZV	Tomato yellow leaf curl Tanzania virus
TYLCV	Tomato yellow leaf curl virus
UMADEP	Uluguru Mountains Agriculture Development Project
USA	United State of America
WAT	Week after transplanting
WFL	Whitefly

CHAPTER ONE

1.0 INTRODUCTION

Tomato *(Lycopersicon esculentum* Mill*)* of the family solannaceae, originated from the tropics of central and south America, extending from Mexico, Ecuador through Chile. It was transported to Europe, and improved further before reaching the United State and Asia (Kalloo, 1993). It is now the most widely grown vegetable crop in the world, giving growers' income, expanding export potential and improving the supply of vitamins and minerals in human nutrition (Rawshan, 1996). Tomato can be processed and canned easily as a whole fruit or as juice, sauce, paste or powder or eaten raw, alone or in combination with other foods.

Generally the tomato yield ranges from 1 to 23 t/ha in tropics as compared to 10 to 22 t/ha in temperate zones (Lannoy, 2001). In Tanzania tomato is grown in almost all parts of the country. The major growing regions are Mbeya, Iringa, Tanga, Kilimanjaro Arusha and Morogoro (MOA, 1995).

Tomato production constraints include abiotic and biotic factors. Literature indicates that optimal temperature for tomato production is about 25^0C and affects crop performance as it rises above 25^0C (Oliveira and Calado, 1996). Biotic factors are weeds, disease and insect pests (Rwezaura *et al.*, 2005). Worldwide, insect pests, diseases and weeds cause an estimated loss of 13-16%, 12-13% and 10-13%, respectively. In East Africa, yield losses can be as high as 88% and pests account for 56% (CABI, 2004).

In Morogoro, tomato production is carried out in two main phases, it is grown as a sole crop after rain season following paddy in lowlands to take advantage of residual moisture and later during the dry season under irrigation. Survey results (UMADEP, 2003) indicated six categories of tomato farmers comprising of rich, poor, youth, old, male, and female. Tomato production is an input intensive activity, which requires a significant amount of cash resources. High input costs limit tomato cultivation to only those farmers who can commit such costs. As a result yields vary depending on inputs and management. Available figures indicate that yields can be as high as 16.5 tons/ha under intensive management and as low as 2.2 t./ha under poor management (UMADEP, 2003).

Currently, most farmers cultivate and weed 2 - 3 times to control weeds. They also use insecticides and fungicides routinely to control insect pests and diseases respectively. These practices lead to unnecessary added costs, soil pulverization as well as elimination of natural enemies. According to baseline survey on tomato production at Kipera and Mlali indicated that, seeds, pesticides (insecticides and fungicides) and inorganic fertilizers were the most important inputs for tomato production (Maerere *et al.*, 2006)

This study therefore, was carried out with the following objectives:

i) To assess pest and beneficial insects' population dynamics under different pest management techniques.
ii) To assess the effects of these management practices on tomato growth and yield.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 An overview

Tomato is one of the most important vegetable crops in Sub-Saharan Africa. In Tanzania, tomato ranks first in acreage and second only to cabbage in production and economic value. A large number of farmers cultivate not more than one hectare per household (Abate *et al*., 2000). The average yields for year 2001 to 2004 was 7.63 t/ha (FAO, 2004). Besides generating income and employment opportunities for farmers, the vegetable is an essential source of vitamins and minerals for the population in the region.

2.2 Constrains to Tomato Production

In Tanzania tomato production is usually associated with biotic and abiotic stresses. The biotic stresses include insect pests such as fruitworm (*Helicoverpa armigera*), leafminer (*Lilioryza* spp.) and whitefly (*Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae); diseases namely early blight (*Alternaria solani* Soraue), anthracnose (*Colletotrichum* spp.) and septoria leaf spot (*Septoria lycopersici*); nematodes (*Meloidogyne* spp); weeds such as sedges (*Cyperus* spp.) and broadleaf weeds. Physiological disorders such as fruit crack and sunny scotch (Rwezaura *et al.,* 2005) are associated with abiotic stresses such as a dry spell, moisture shortage, high temperature, and solar radiations that prevail in the environment (FAO, 1988).

2.2.1 Insect pests

Tomatoes wherever grown are host for many kinds of insects. All parts of the plant offer food, shelter and reproduction sites. Insects can cause unthrifty growth or death of tomato plant and damage to fruits (Lange and Bronson, 1981). Insect pests include the American bollworm or tomato fruitworm, which can cause yield losses as high as 70% green peach aphids (*Myzrus persicae)*, thrips *(Frankliniella occidentalis)* and leaf miners (*Lilioryza* spp) (Rappaport, 1992). Bushy host plants with large leaf surface area provide habitat and oviposition site for bollworms (AVRDC, 1990).

Infestation by leaf miner begins in lower leaves of the crop and proceeds through the middle leaves to those of the upper canopy reducing photosynthetic area of the plant Fracknath (2005).

Although thrips appear to prefer flowers (de Jager *et al.,* 1993; Gerin *et al.,* 1999), they also readily feed on leaves and stems (Schuch *et al.*, 1998; AVRDC, 2002) thus, reducing photosynthetic area. Female thrips deposit most of their eggs in the leaves rather than the stems or flowers (Kiers *et al.,* 2000) and prefer younger leaves to older leaves for oviposition (de Kogel *et al.,* 1997). Thrips have been found to be serious pest during cool dry season when tomatoes are grown (AVRDC, 2002).

The whitefly has been a major agricultural pest of field and horticultural crops world-wide since the early 1980s (Brown *et al.*, 1995; Oliveira *et al.*, 2001). Heavy losses due to whiteflies have been recorded on many crops in various agricultural systems and in greenhouses (Oliveira *et al.*, 2001). Damages are caused primarily by phloem-feeding by their nymphs and adults, phytotoxic disorders that they cause such as irregular ripening, as well as transmission of plant viruses. Nymphs and adults of both stink bugs and leaf footed bugs suck juices from green fruit leaving a puncture, which later may become surrounded by a discolored zone due to invasion of secondary pathogens. The trap crop should be sprayed before stink bug nymphs become adults. Weed management in and around the field prior to planting the crop is important to destruct their habitats thus creating insect free environment (Webb *et al.*, 2006).

2.2.2 Diseases

Tomato cultivation in Africa is constrained by many diseases. Major diseases include late blight (*Phytophthora infestans* (Mont.) de Bary), bacterial wilt (*Pseudomonas solanacearum* Smith), early blight (*Alternaria solani* Soraue), root- knot nematodes (*Meloidogyne* spp.) and some viral diseases (Mehron, 1980; Gielen *et al.*, 1996; Tumwine *et al.*, 2002). Tomato foliage and fruit infections by late blight contribute to significant yield losses during the rainy season (Yesuf, 2005; AVRDC, 2002, 2001).

In Cameroon total yield losses caused by late blight foliage infection of tomato have been reported (Fontem *et al.*, 2003). Septoria leaf spot *(Septoria lycopersici)* is a foliar disease, its infection occur on leaves at all developmental stages of the crop due to presence of season-long inoculum (Ojiambo and Sherm, 2005). Studies in other Septoria pathosystems have documented the inhibition of spore germination in conditions of high light intensity (Elmer and Ferrandino, 1995; Ferrandino and Elmer, 1996).

Tomato yellow leaf curl Tanzania virus diseases (TYLCTZV) have been reported to be prevalent in six surveyed regions which are Arusha, Dodoma, Iringa, Morogoro, Kilimanjaro and Coastal regions (Kashina *et al.*, 2003). In Tanzania tomato yellow leaf curl virus (TYLCV) was detected in three widespread weeds, *Achyranthes aspera, Euphobia heterophylla* and *Nicandra physalloides* serving as major reservoirs (Nono-Womdim *et al.*, 1996). Furthermore, twenty six plant species have been reported to be potential reservoir for TYLCTZV as they either occur in abundant population within the tomato farms, they are associated with whitefly vectors and many were found naturally infected with TYLCTZV (Kashina, 2003). For example weeds such as *Amaranthus* and wondering jew (*Commelina* spp.) have been noted to harbor all stages of whitefly, germinivirus vector (Omondi *et al.*, 2005).

Root-knot nematodes are often cited as major limiting factors of tomato production resulting into estimated production losses as high as 50% in tropics. In Tanzania all tomato growing regions have been fount to be infected by root-knot nematodes. According to Nono-Womdim *et al.* (2002), four nematode species, namely *M. hapla*, *M. javanica*, and *M. incognita*, are associated with tomato root knots in Tanzania; however, *M. javanica* is the most common and most widespread species. *Meloidogyne . javanica*, and *M. incognita* have been also reported to infect upland rice (Bridge *et al.*, 1990). Although initial density of nematodes in the soil directly influences nematode populations and their subsequent pathogenic effects (Mabagala *et al.*, 1996), populations of root-knot nematode are lower on susceptible dry season crops following flooded lowland rice (Netscher and Sikora, 1990; Castillo *et al.*, 1976).

2.2.3 Weeds

Weeds interfere with other plants by competing for light, water and nutrients as well as releasing allelopathic compounds (Morales-Payan, 2003; Akobundu, 1987). They also harbor insects and diseases, which may then spread to vegetables and reduce crop yields and quality. Drost and Doll (1980) reported inhibition of growth on some crops by yellow nutsedge tubers and leaves.

Problem weeds in tomatoes include perennials, dodder, weeds of the solannaceous family, and grasses. Purple (*Cyperus rotundus* L.) and yellow nutsedges (*Cyperus esculentus* L.) are considered among the worst weeds in the world (Stall and Morales-Payan, 2003).

Their success as weeds in vegetable crops is based on tuber dormancy their rapid and abundant reproduction, widespread distribution and difficulty in control (Bewick, *et al.*, 1995; Holm *et al.*, 1991). Wet conditions in lowland rice growing fields have been reported to favour sedge growth and poplation (Sibuga, 2002). According to Morales-Payan *et al.* (2003), the belowground interference of nutsedges (yellow and purple) with tomato reduced concentrations of nitrate in the sap of tomato by more than 18% and under full interference tomato shoot weight was reduced by 34% compared to tomato grown under no interference. Experiment has shown that in nutrient culture weeds reduced tomato weights by 50% (Zimdahl, 1980).

2.3 Pest management practices

2.3.1 Chemical control

2.3.1.1 Insects

Tomato agroecosystem requires intensive insecticide applications in order to keep insect pests below their economic thresholds. However, insecticide applications that control arthropod pests effectively can be directly toxic to diverse predatory arthropod populations as well as having sub lethal and indirect effect on predator populations in tomato ecosystem (AVRDC, 2003). The direct effects reduce predator populations through toxicity while the indirect effects are mainly due to shortage of food caused by killing their insect hosts, and also because the predators may migrate away from pesticide treated fields (Vardim and Edward, 1998). According to Kee *et al.*, (2007) action threshold for aphids and mites is 50% or more of terminals with five or more aphids and 20 mites per leaflet, respectively and An action threshold of approximately 45% of flowers with 5 or more adult western flower thrips is recommended (Steiner and Goodwin, 2005).

Men *et al.* (2004) found insecticide applications against other insect pests decreased the densities of mites significantly and; Vandekerkhove and de Clercq (2004); Hoffmann and Frodsham (1993) reported that nymph and adults of green stink bug (*Nezara viridula*) were highly susceptible to insecticide both by ingestion and contact exposure. Vardim and Edward (1998) also reported that killing of prey caused food shortage thus predators were starved.

Vardim and Edward (1998) reports from 1994 and 1995 studies at Ohio State University indicated that fungicides and herbicides caused increase in the number of natural enemies by as high as 55%. Miranda (2005) found that under excessive insecticide applications predators populations were severely reduced more so than parasitoids.

2.3.1.2 Diseases

Chemical control of tomato diseases depend on timing spray and use of appropriate chemicals, both in the seedbed and in the field. Several broad-spectrum and systemic fungicides are used for late blight control while, for early blight and septoria leaf spot several fungicides are used. In Cameroon, late blight protection in tomato heavily depends on fungicide applications (Fontem *et al.*, 1998). According to Fontem (2001) three applications of Ridomil Plus® at the rate of 2.4 kg a.i /ha reduced late blight intensity in potato. Samoucha and Cohen (1989) reported that a mixture of systemic and contact fungicides controls late blight more effectively than the fungicides applied individually. Through experiment pretreatments of tomato plant with the chemical di-3-amino butyric acid or preinoculation with tobacco necrosis virus both of which induces systemic acquired resistant (SAR) in the tomatoes protecting them from late blight infection (Agrios, 2005).

According to AVRDC (1997), the use of fungicides such as Ridomil and Mancozeb is the only control method for late blght. Ridomil MZ-63.5% WP that is both systemic and protectant in action gives the best (78.8%) late blight control. Bekele and Hailu (2001) reported that 5 and 3 applications of protective fungicides such as Brestan 10, Mancozeb and Chlorothalonil; and preventive fungicide like Ridomil MZ respectively, reduced late blight in susceptible varieties.

2.3.1.3 Weeds

Weeds compete for light, water, and nutrients (Kere *et al.*, 2003) and may host tomato diseases, such as tomato yellow leaf curl virus (AVRDC, 2000). Transplanted tomatoes and peppers during their early days require 4 to 5 weeks weed-free while 8 weeks are required for direct seeded peppers. Nutgrass grows most rapidly in full sunlight when adequate water and nutrients are available. There are effective herbicides for nutgrass control, one of which is glyphosate (Roundup®) because it kills the underground tubers connected to the leaves. According to Adejonwo *et al.* (1991) findings, the use of pre-emergence herbicide mixture of Metolanchlor plus Prometryne at 2.0 and 1.0 kg a.i/ha, respectively, showed promising effective weed control.

2.3.2 Cultural control

Cultural control may not by itself reduce the pest population to below economic threshold level, but it is one of the oldest and most effective methods in reducing losses due to insect pests (Glass, 1975). Classical control measures that have been tested and recorded with some success are avoidance, irrigation, mulching, manuring and fertilization, intercropping (Helenius, 1998), trap cropping (Hokkanen *et al.*, 1991), rotation and clean cultivation among others. Early planting can also be an effective way of avoiding whiteflies because they reproduce more rapidly under hot, dry conditions.

According to Norsworthy (2003) and Norsworthy and Meehan (2005) competitiveness of tomato and bell pepper is increased over yellow nutsedge when soil is amended with wild radish, while yellow nutsedge tuber production and size is reduced. Sanitation alone, or in combining with sheltering and intercropping, prevented late blight epidemics (Tumwine *et al.*, 2002).

Weeds are a serious problem in tomato fields and involve a lot of labor and funds to get the crop free of weeds. In Tanzania hoe weeding is the most common traditional method of weed control. Farm labour required for hoe weeding is relatively more expensive and often in short supply during the early stages of crop growth when weed competition is more severe (Gondwe, 1987). Timely weeding particularly before the onset of flowering is important in order to realize increased yields and free the crop of insect vectors such as whiteflies and thrips (FAO, 1988).

2.3.2.1 Mulching

Mulching is the practice of covering the soil with materials such as dry grass, litter and plastic sheets. Mulching is recommended to reduce weed competition, soil compaction, soil erosion, to maintain a uniform root environment and conserve soil moisture. Mulches control weeds by excluding light and by forming a physical barrier to their growth. An optimum mulch of 7.5 t./ha (Hudu *et al.*, 2002) of grass materials and 5 t./ha of rice straw were observed to result in effective weed suppression; better crop growth, optimum root temperatures and high yield of tomato. Organic mulches provide good control of annual weeds, but perennial weeds may be able to push through the mulch layer (Stall, 1996). However, depending on the type and source of mulches, some weed types have been introduced in the area because of mulch use e.g. rice husks and dry grasses contribute largely to weed introduction to an area (Rweyemamu *et al.*, 1998).

Apart from checking weed growth, mulching improves the vegetative and flowering performance and significantly increases the fruit yield of tomato over bare ground by 8.09 t/ha more (Sunilkumar and Jaikumaran, 2002).

Summer *et al.* (2004) found wheat straw mulch significantly delayed and reduced the incidence of alate aphids (*Aphis gossypii*) and several aphid-borne cucurbit viruses in zucchini squash. The incidences of silverleaf whitefly (*Bemisia argentifolii*) and squash silverleaf syndrome were also significantly reduced. When studying the effect of reflective mulch on whitefly population dynamics, Frank and Lihurd (2005) reported higher whitefly adults and nymph populations in lower plant strata.

According to Kashina (2003) application of mulch on seedbeds delayed spread of tomato yellow leaf curl Tanzania virus (TYLCTZV) disease for at least two weeks by discouraging vector landing on the crop due to the repelling effect of silver colour of the mulch at early stage of growth.

Mulching reduces disease levels by lowering the amount of initial inoculum early in the season by preventing the leaves from contacting the soil as well as reducing water splash. According to Lyimo *et al.* (1987), low amount of initial inoculum reaching the plant reduced blight disease levels as well as improving plant growth which increases tolerance to nematodes.

2.3.2.2 Fertilization

Primary concern of fertilization is to provide the proper level of nutrients required at any stage of plant development (Jones *et al.*, 1993). In the tropics, common fertilizer application rates are 60 - 120 kg N/ha, 60 - 140 kg P_2O_5/ha, and 60 - 120 kg K_2O/ha. It is recommended that half of the fertilizer be applied as a basal dose and the remaining fertilizer be added at first fruit-set (AVRDC, 2000).

Changing the nutritional composition of leaves artificially, through the addition of fertilizers, has been shown to change the preference, growth, and development of insects feeding on them, either directly through their effect on host tissue nutrient levels (Altieri and Nicholls, 2003), or indirectly through altered host plant morphology (Moon and Stiling, 2000).

Fertilization has been shown to affect all three categories of resistance, which are preference, antibiosis and tolerance (Altieri and Nicholls, 2003). The most common glandular trichomes (0.2 - 0.4 mm in length) have been reported to be responsible for the mortality of green peach aphids (Simmons *et al.*, 2003). However, high rates of NPK have shown to reduce trichome-based resistance and lamellar-based resistance against insect pests of tomato (Barbour *et al.*, 1991).

Higher levels of leaf nitrogen may enhance both growth and reproduction of herbivorous insects (Phelan, *et al.*, 1995; Mattson, 1980). An increase in the nutrient content of the plant maybe argued to increase its acceptability as a food source to pest populations. On field-grown tomatoes, the abundance of *F. occidentalis* increases with increasing rates of fertilization (Stavisky *et al.*, 2002; Brodbeck *et al.*, 2001). Brodbeck *et al.* (2001) suggested that *F. occidentalis* prefers to feed on flowers rather than leaves because pollen has high nitrogen content. However, within-plant distribution of *F. occidentalis* is influenced by the phenology of the plants rather than fertilization levels (Chau *et al.*, 2005). The reduction in aphid and flea beetle infestations in the organically fertilized plots was attributed to lower levels of free N in the foliage of plants. However, later in the season, in these same plots, insect population levels were lowest in organic plots for beetles, aphids and lepidopteran pests. This suggests that the effects of fertilizer type vary with plant growth stage (Altieri and Nicholl, 2003). Phelan *et al.* (1995) reported that N fertilization increased soluble N levels in plant tissue which generally decreased pest resistance.

2.3.2.3 Intercropping

Intercropping of crop plants is common in the tropics with effect on pest population dynamics that minimize crop damage. However, intercropping ensures food security and additional income of farmers.

Intercropping and trap crops are used as habitat diversification strategies in pest management due to their preferred growth stage, cultivar, or species that divert pest pressure from the main crop because they are more attractive (Cook *et al.*, 2007). Intercropping may affect population of insect pests by any of following mechanisms; modifying the microclimate and in turn affecting population of pests and their natural enemies; acting as barrier to insects movement; changing the physiological status of the crop through competition for growth resources; and interfering with host seeking ability of pests and, providing a congenial niche for natural enemies of pests (Liping, 1991) cited by Girma *et al.* (2003). Root (1973) proposed the natural enemy hypothesis which says that increased plant diversity leads to increased natural enemy densities.

Tomato intercropped with maize, onion or garlic and beans have been observed to reduce insect pest, disease and weed incidences (Tumwine *et al.*, 2002). Small plot studies on tomato as a target crop have shown the potential of short duration pigeon pea as a 'trap' crop for diverting the oviposition by fruitworm adults (Sithananthan *et al.*, 2005). Similar results were reported by AVRDC (2001) when *Solanum nigrum* was used in Taiwan.

In studies conducted in Colombia, intercropped maize recorded 25% fewer leafhopper adult (*Empoasca kraemeri*), 45% fewer beetles (*Diabrotrica balteata*) and 25% less fall armyworms (*Spodoptera frugiperda*) than sole cropped maize (Ogenga-Latigo, 1993). Furthermore, Ogenga-Latigo *et al.* (1992, 1993) and, Tingey and Lamonte (1989) also found lower aphids (*Aphis fabae*) population on beans intercropped with maize than sole cropped beans. Host-plant finding is affected by the size (weight, leaf area, height) of the surrounding non-host plants (Finch *et al.*, 2003). In contrast to insect pests, diversified systems and crops bordered with different vegetation (other crop fields, weeds and forests) recorded more predators than monocrops and crops adjacent to vegetation free fields. According to Munyuli *et al.* (2007) increased number of predators in intercropped crops is attributed to the crops canopy providing more food and shade which allows development of their eggs or larvae. Jones and Gillett (2005) reported nearly the same abundance and diversity of beneficial insects as strip plants themselves.

Intercropping can give a reduction in fungal diseases incidence and severity (Boudreau and Mundt, 1992; Boudreau, 1993). Intercropping with cowpeas reduced bacterial wilt (*Pseudomonas solanacearum*) on tomato (Michel *et al.*, 1997).

Literature surveys conducted by Liebman and Dyck (1993) indicated that weed biomass production might be markedly reduced using intercropping (spatial diversification) strategy.

2.3.3 Integrated pest management (IPM)

Integrated pest management (IPM) is a pest control strategy that uses an array of complementary methods: mechanical device, physical device, genetical, biological, legal, cultural management and chemical methods (Jahan, *et al.*, 2007). It is an ecological approach with a main goal of significantly reducing or eliminating the use of pesticides. IPM is the most efficient system of pest control due to presenting similar productivity and 65.6% less pesticide applications than in the calendar system (Miranda *et al.*, 2005).

Cultural practices are regarded to be compatible options under the IPM approaches. Use of pathogen free seed, a two to three year crop rotation, sanitation by deep plowing of diseased plants and use of resistant curtivars could help to control the disease (Agrios, 1987).

The combination of products containing mancozeb and azoxystrobin as active ingredient with scouting and rouging of visibly diseased plants provided sufficient practical and desirable level of late blight control (Becktell *et al.*, 2005). According to Fontem (2001), use of resistant varieties and two foliar sprays of Ridomil Plus® at a 21 day interval have been suggested to be incorporated into integrated pathogen management scheme for potato late blight.

Intercropping tomato with soybean (*Glycine max*) or sesame (*Sesamum indicum*), with sanitation (removal of diseased plant tissues), have shown to limit late blight development, but taller intercrops suppressed tomato growth and production (Tumwine *et al.*, 2002).

With regard to weeds, more-effective weed control in agricultural fields can be achieved by utilizing information about the spatial distribution of the previous year's mature weeds.

This allow reduces the number of weeds reaching maturity by combining cultivation, hand-weeding and herbicide treatment (Martina and Lanini, 2005) According to Polomski and Shaughnessy (2002) annual weeds can be controlled using a combination of mulches and hand weeding and herbicides are not needed.

CHAPTER THREE

3.0 MATERIALS AND METHODS

The study involved three experiments. One experiment was conducted in 10 farmer managed tomato fields at Mlali and Kipera villages aiming at monitoring of relative importance of tomato pests, and the other two were conducted at Sokoine University of Agriculture (SUA) Horticulture unit as On-station field experiments.

3.1 Pest monitoring in farmers' fields

The study was conducted from August to October 2006 at Kipera and Mlali villages in Mlali ward, Mvomero district. The fields were under paddy and maize production, respectively during the previous season. At Mlali village all five farmers' fields were located at the irrigation scheme (lowland) used for paddy rotated with tomato production (Table 1, Appendix I). Purposive selection of five tomato growers' fields in each village was done based on field having an area of not less than 0.5 acres and acceptance of the study by the farmer. At Kipera village each field was divided into four quadrats (Fig. 1a) and at Mlali irrigation scheme the fields were divided into five equal sections (Fig. 1b), as the fields are rectangular in shape. At the center of quadrats/ sections and field, a 2 m x 2 m sampling area was pegged for data collection,

Randomized complete block design (RCBD) was used, whereby farmers' tomato fields were used as treatments as farmers differed in tomato management practices (Table I) and the five sampling areas in each field as replicates. In each sampling area five plants were used for data collection.

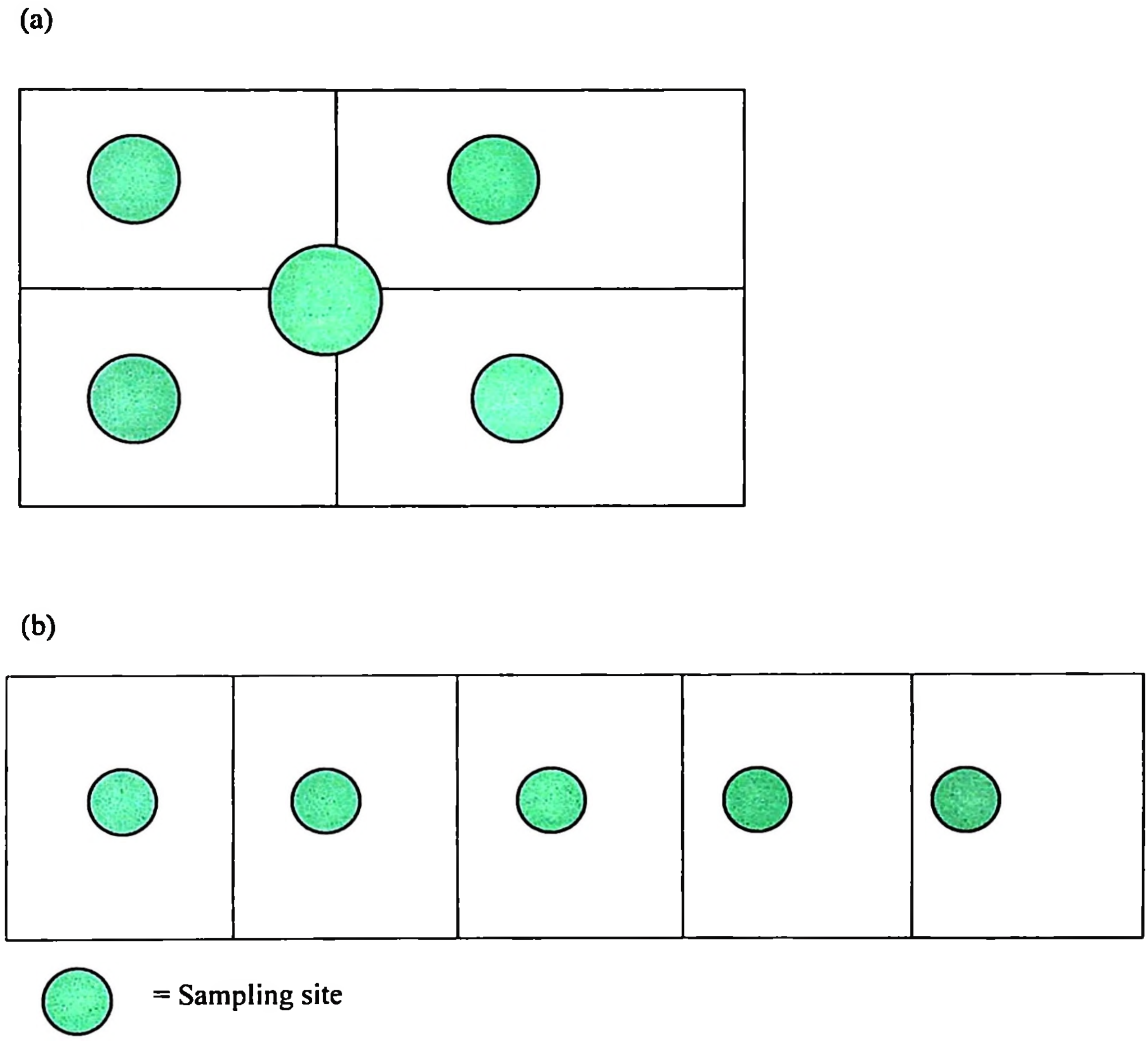

Figure 1: Layout in Farmer fields (a) Kipera (b) Mlali

Table 1: Tomato field management practices by farmer

Farmers' Field	Treatment (Management practices)				
	Variety	Cropping system	Fertilizer (s)*	No. of sprays per season	
				Fungicides	insecticides
K1	CALJ	Monocrop	SA	3	5
K2	Orynx	Monocrop	SA	7	7
K3	Tanya	Monocrop	Urea, Mult K	5	5
K4	CALJ	Monocrop	Urea, CAN	5	6
K5	CALJ	Intercrop (Maize)	Urea, Mult K	3	5
M1	Orynx	Monocrop	Urea, DAP	5	2
M2	Tanya	Monocrop	DAP, Urea, Mult K, CAN	8	8
M3	CALJ	Monocrop+Mulch	DAP, Urea, Mult K, CAN	8	8
M4	Orynx	Intercrop (Maize)	DAP, SA, Mult K, CAN	6	7
M5	CALJ	Intercrop (Maize)	SA	5	5

* Fertilizers are arranged according to application sequence during the crop growing season. K1 - K5 = Kipera farmers' fields, M1- M5 = Mlali farmers' fields, SA = Sulphate of ammonium, CAN = Calcium ammonium nitrate, DAP = Diammonium phosphate, Mult K = Foliar potassium fertilizer

3.1.2 Data collection

3.1.2.1 Field management practices

Initially, each farmer was interviewed on; tomato variety grown, seed source and whether basal fertilizer was applied during transplanting in tomato field and recorded. Through observations cropping system (monocropping or intercropping) as well as other management practices were recorded. On subsequent scouting dates, tomato growers were interviewed on fungicide(s), insecticide(s) and fertilizer(s) applied since last field scouting.

3.1.2.2 Pest assessment

3.1.2.2.1 Insect pests

Before flowering three uppermost leaves from the tip were observed on the presence (+) or absence (-) of aphids, counting of thrips, bollworm eggs and its larva, however, after flowering, the leaf just below the first flower cluster and first flowers were used for observing the above mentioned insects though thrips were counted on five flowers on each plant. Medium aged (4^{th}, 5^{th} and 6^{th}) leaves were used for observing presence (+) or absence (-) of leaf miner, counts of whitefly colonies and mites. The number of infested plant(s) by aphid and leafminer were recorded as percentage infestation and total counts for other insects were recorded.

3.1.2.2.2 Diseases

Plants were inspected to get a general picture of disease distribution. Three representative leaves were selected from each sample plant and scored for early blight, late blight and leaf spot diseases. Disease rating according to severity was 1 = 0%, 2 = $\leq$ 10%, 3 = 10-50% and 4 = $\geq$ 50% (Appendix II).

3.1.2.2.3 Weeds

A wooden frame of 0.25 m x 0.25 m was used to establish a quadrat at the center of the 2 m x 2 m sampling area for recording weed counts and weed dry matter yields. Weeds were counted and harvested twice; first at two weeks after transplanting but before first weeding and second at two weeks after the first weeding. Grasses, broadleaf and sedge weeds were counted and harvested by species and dried at 80^0C for 72 hours to obtain constant dry weight.

3.1.2.2.4 Nematodes

Five non-senesced plants were uprooted just after last harvest from each farmer field (one plant per sampling area) to observe presence (+) or absence (-) of root knot nematodes. The number of infested plant(s) by nematodes was recorded as percentage infection.

3.1.2.3 Beneficial Insects

This involved counting the number of any beneficial insects including; stink bug (*Nezara viridula*), lacewing (*Chrisoperla rufilabris*), ladybird beetle (*Cheilomenes sulphurea*) and spider (*Stethorus punctillum*) on the three uppermost leaves from the tip of the sample plant. After flowering, the third leaf below the first flower cluster and first flowers were used. However, spider counting included the ones found on the plants and on the ground. Flying insects such as bees and butterfly were recoded per square meter.

3.1.2.4 Yield determination

Tomato fruits were harvested from two tagged plants within the sampling area. The half red ripe to red fruits were categorized as; i) marketable fruits (fruits with smooth, glossy surface and firm skin); ii) physiologically damaged fruits (fruits with blossom end rot, cracks and sunny scotched; iii) insect damaged fruits based on a decision key as large, deep holes anywhere on fruit surface (tomato bollworm); small puncture surrounded by light discolored spot (stinkbug, leaf-footed bug); fruit dimpled and distorted (leaf footed bug) and irregular ripening (whiteflies); and iv) disease-damaged fruits, disease symptoms on fruits were used. For each category fruit number and weight were determined and recorded.

3.1.3 Statistical model

$Yi = \mu + \beta + ti + \varepsilon i$, where Yi = observed response value, μ = general effect or an overall mean, β = blocking effect; ti = treatment effect and εi = a random error term.

3.1.4 Data analysis

The SPSS computer program was used to determine frequency on varieties grown, cropping systems and agrochemical usage. Data on pest prevalence was subjected to analysis of variance (ANOVA) using the MSTATC computer program package.

Before proceeding with ANOVA all the insect and weed count data were subjected to square-root transformation and percentage records were subjected to arc- sine transformation (Gomez and Gomez, 1984), however, no transformation was done for disease score. All data were subjected to analysis of variance (ANOVA) using the MSTATC computer program package. All tests were carried out at 5% level of significance and comparison of means was done using Duncan's Multiple Rage Test (DMRT).

3.2 On-Station experiments at Sokoine University of Agriculture (SUA) Horticulture unit

3.2.1 Assessment of tomato pests under different management practices

A field experiment to evaluate seven tomato management techniques effect on pests was conducted from October 2006 to February 2007 at Sokoine University of Agriculture (SUA) Horticulture unit at Morogoro region located at lat. 6^0 05' S, long. 37^0 37' E and 525 meters above sea level. The experimental period coincided with short rains season (Appendix III). The soil at the experimental site was sandy loam (Appendix IV). Before this study the site had been under tomato and African eggplant production.

The experiment consisted of two determinate tomato varieties (CALJ and Tanya) and seven tomato management techniques (Table 2):

The experiment was laid out in split treatment combinations in randomized complete block design (RCBD) with five replications. Each plot consisted of 10 cm raised planting bed, 4.8 m long and 3.6 m wide. Main plots; subplots and replications were separated by 1.0 m alley. Plots for IPM treatment were prepared and irrigated once per week for three weeks to encourage weed seeds germination and growth prior to herbicide application. Herbicide, glyphosate (Round up®), was applied one week prior to transplanting. On 16/11/2006, four week-old tomato seedlings were transplanted in single rows spaced at 0.90 m between row and 0.36 m within the rows giving a plant population of 32 plants per plot.

Table 2: Tomato management techniques (Treatments)

S/N	Treatment	Description
1	Fertilizer application	NPK (20: 10:10) applied at the rates 74 kg N/ha, 31 kg P/ha and 31 kg K/ ha
2	Mulching	Dried grass at a thickness of 10 cm
3	IPM	Herbicide (glyphosate) at rate of 3.8 kg a.i/ha (10.5lts/ha) applied one week prior to transplanting, insecticide (Karate) at the rate of 0.12 kg a.i/ha (2.3 lts/ha) and fungicide (Ridomil at the rate of 2.4 kg a.i/ha (5.8 kg/ha) or Dithane at the rate of 3.4 kg a.i/ha (4.3 kg/ha).
4	Tomato/cabbage	Tomato intercropped with cabbage (cv. Romenco). Cabbage spacing 0.6 m within row (three rows)
5	Grower standard	No basal fertilizer. Fertilizer (Urea 46%N) application (10 g/plant) at the rate of 138 kgN/ha before first weeding and at flower setting respectively. Calendar (once per week) applications of fungicide (Dithane M45) and insecticide (Karate) mixed.
6	Check	No weeding, no fertilization and no insect pests and disease contolling.
7	Tomato/spider plant intercropping	Tomato intercropped with spider plant (*Cleome gynandra* L) (green stem). Spider plants spacing 0.7 m (three rows).

3.2.2 Data collection

Data collection involved pests and beneficial insects scouting which was done throughout the growing season on weekly basis. Data were collected from the two central rows (12 plants).

3.2.2.2 Pest assessment

3.2.2.2.1 Insect pests and beneficial insects

The same scouting procedures for insect pests and beneficials as described in section 3.1.2.2.1 and 3.1.2.3, respectively, was followed.

3.2.2.2.2 Diseases

Similar disease inspection and rating (severity) as described in section 3.1.2.2.2 was done and plants with curled leaves (viral infection symptoms) were counted and recorded as disease incidence.

3.2.2.2.3 Weeds

Counting and harvesting was done as described in section 3.1.2.2.3. However, instead of 0.25 m x 0.25 m. quadrat two 0.5 m x 0.5 m quadrants were established at least one meter away from both ends of each plot.

3.2.2.2.4 Nematodes

Similar procedure described in section 3.1.2.2.4 was used.

3.2.2.3 Yield assessment

3.2.2.3.1 Yield components

At the 8^{th} week, the number of branches, fruit clusters and fruits per cluster were recorded from six plants and average number per plant was recorded. However, iron frame with five holes varying in diameters was used to grade clean marketable fruits according to their size based on (1 - 5) scale (unpublished) whereby, 1 = 4 cm (very small); 2 = 4.5 cm (small); 3 = 5.5 cm (medium); 4 = 6.5 cm (large) and 5 = 8.0 (very large) (Appendix V).

3.2.2.3.2 Total yield

Tomato fruits were harvested from six plants within two center rows. Fruits were considered ready for picking when 50% of fruits turned red. Harvested fruits were categorized as clean marketable fruits (smooth, glossy surface and firm skin); physiologically damaged (blossom end rot, cracked and sunny burn). Insect damaged fruits were sorted out using a decision key (large, deep holes anywhere on fruit surface (bollworm); small puncture surrounded by light discolored spot (stinkbug, leaf-footed bug); fruit dimpled and distorted (leaf footed bug) and irregular ripening (whiteflies). Disease symptoms on fruits were used for disease-damaged fruits. For each fruit category the number and weight were determined and recorded.

3.2.3 Data analysis

Before proceeding with analysis of insect and weed count, data were subjected to square-root transformation and percentage of insect infested plants data were transformed using arc-sine (Gomez and Gomez, 1984). All data were subjected to analysis of variance (ANOVA) using MSTATC statistical program. All tests were carried out at 5% level of significance and comparison of means was done using Duncan's Multiple Rage Test (DMRT).

3.2.4 Statistical model

$Y_{ijk} = \mu + Ai + \varepsilon_i + B_j + (AB)_{ij} + \varepsilon_{ijk}$; whereby, Y_{ijk} = Response effect, A_i = Effect of ith level of factor A, μ = general mean common to all observations, B_j = Effect j^{th} level of factor B, $(AB)_{ij}$ = interaction effect of i^{th} level of factor A and j^{th} level of factor B; ε_i = random error due to i^{th} levels of factor A and ε_{ijk} = random error or random effect specific to each experiment.

3.3 Assessment of tomato-spider plants intercrop on tomato insect pests

The experiment was conducted at Horticulture Unit at SUA-Morogoro during June – October 2007. The experiment comprised of one tomato variety (Tanya) and three treatments (viz. intercrop with spider plants (green stem), spider plant and tomato monocrops (checks). The seedlings of tomato and spider plant were raised at nursery using sterilized forest soil to get healthier seedlings.

The experiment was laid out as randomized complete block design (RCBD) with three replications. Individual plots were 4.2 m x 3.6 m, in each plot there were 28 plants, 4 tomato rows with 0.90 m x 0.60 m spacing, ten plants at the two central rows were used for data collection. Blocks and plots were separated by 0.1 m alley.

Four and three weeks old tomato and spider plant seedlings, respectively, were transplanted on 1/6/2007, onto raised beds at a spacing of 0.9 m (between rows) x 0.6 m (within rows). In tomato - spider plant intercropping, spider plant rows were alternated with tomato rows. Due to robust vigorous growth of spider plants, harvesting of spider plants was done once per week. Surface irrigation was done twice per week and three fungicide (Dithane 45 M) applications at a rate of 3.4 kg a.i/ha (4.3 kg/ha) were done to control diseases. Two hand-hoe weedings were done after two and four weeks since transplanting, afterwards, hand pulling was done once per week.

3.2 Data collection

Scouting of insects was done twice per week in two weeks consecutively for each tomato developmental stage which are vegetative growth, flowering and fruiting stage. The procedure for insects scouting was as described in section 3.2.2.2.1.

3.3 Data analysis

The Insect counts were transformed by square root transformation while leafminer and aphid incidences were transformed by using arc-sine (Gomez and Gomez, 1984) before analysis of variation (ANOVA). The MSTATC package was used for analysis of variation (ANOVA) and means separation was done using DMRT at P = 0.05.

CHAPTER FOUR

4.0 RESULTS

4.1 Biological monitoring in farmers' fields

4.1.1 Farmers' tomato management practices

4.1.1.1 Cropping system

The result from (Fig. 2a) indicate that CALJ was the most popular variety grown by 50% tomato growers followed by Tanya that was grown by 20% farmers. Eighty percent of farmers purchased seeds from agrochemical dealers, while 20% used their own seeds extracted from previous season's harvest. Seventy percent of tomato growers practiced monocropping while the rest intercropped tomato with maize. Furthermore, only 10% of farmers applied mulch (rice straw) (Fig. 2b).

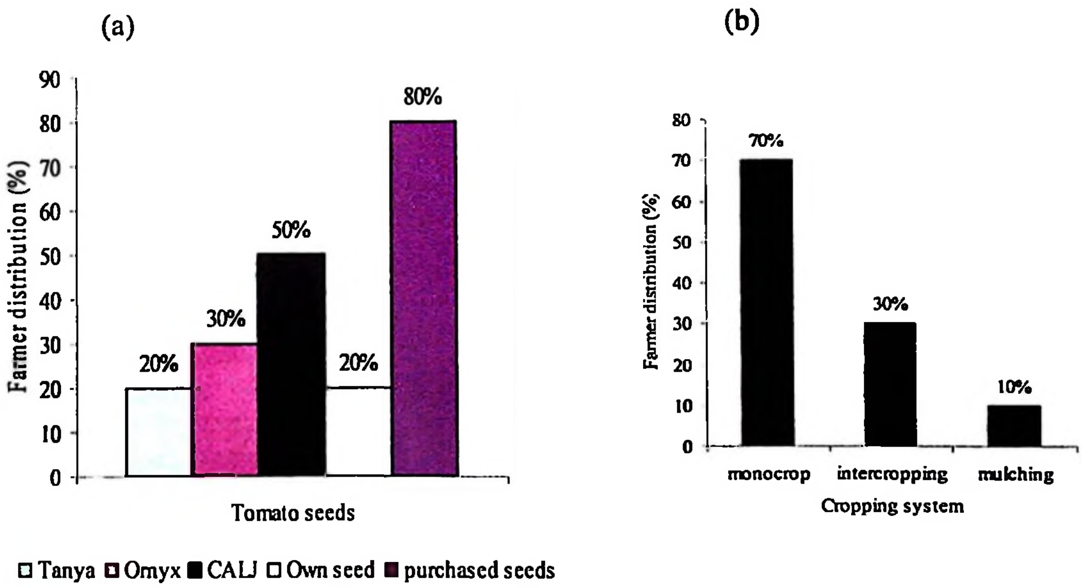

Figure 2: Farmers' distribution on (a) Seed cultivar and source (b) Cropping systems at Mlali and Kipera villages (August - December 2006 growing season)

4.1.1.2 Pesticides use

Results (Fig. 3a) indicate that all tomato growers used insecticides. Karate was used by all tomato growers (100%) followed by Thionex (60%). Furthermore, (Fig. 3b) indicates that

Karate had the highest overall frequency use among insecticides ranging from three to six times, followed by Thionex two to five times per growing season. Selecron was used only once by 10% farmers. Most farmers (50%) used Karate five times while 40% of farmers used Thionex twice per growing season. The maximum number of applications of insecticides was six times per season on Karate 50EC (Fig. 3b).

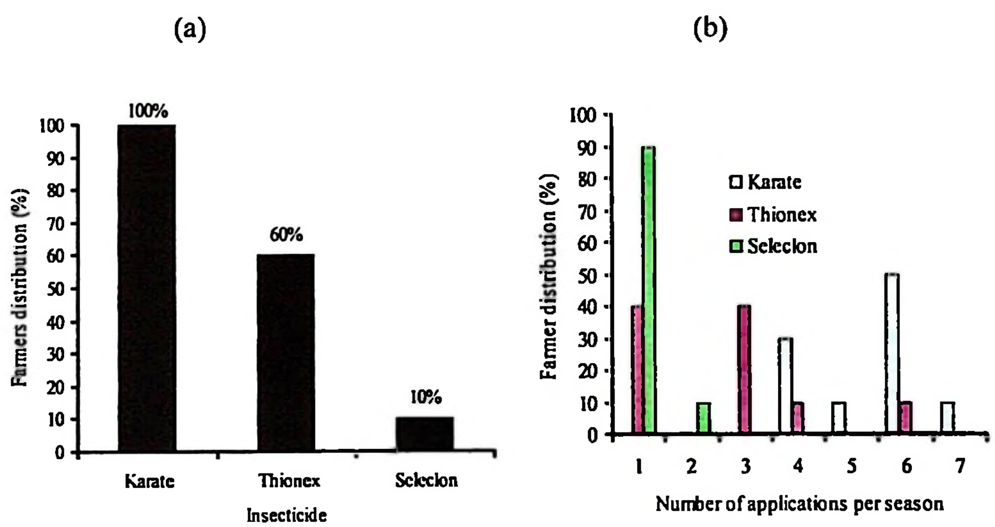

Figure 3: Distribution of farmers on (a) insecticides used (b) frequency of insecticide applications during August - December 2006 season

Results (Fig. 4a) indicate that, 30% of farmers did not use Dithane-M 45 while 50 - 80% of farmers did not use Atracoblue, Farmerzeb, Blue copper and Ridomil. The overall farmer's distribution per respective number of fungicides application was 10 - 30%, however, the maximum number of application of fungicides was six times per season (Fig. 4b).

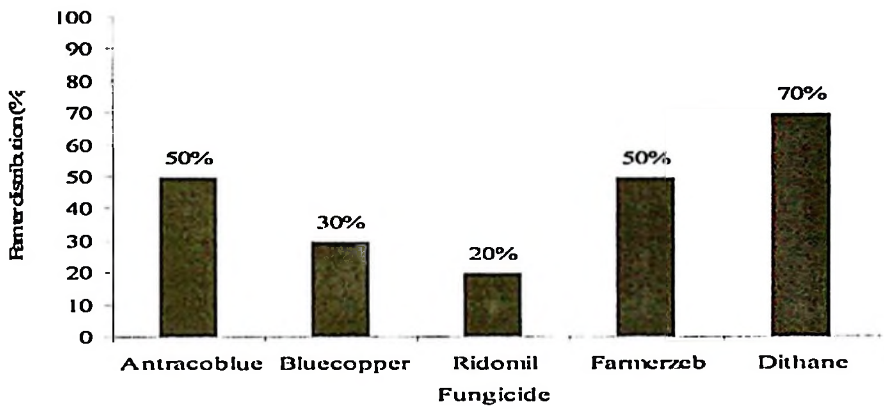

Figure 4a: Distribution of farmers on fungicides used during August - December 2006 season

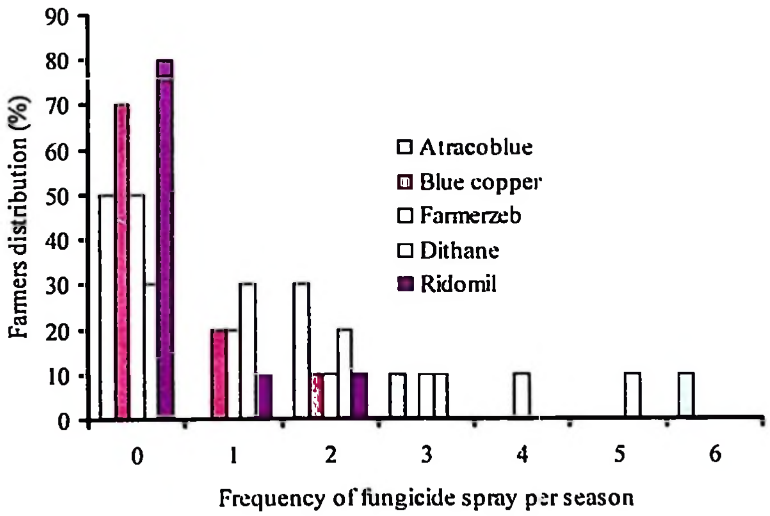

Figure 4b: Distribution of farmers on frequency of fungicide applications during August - December 2006 growing season

Results (Fig.5) indicate that the highest total number of fungicides and insecticides applications per season was eight and the lowest was five. Most farmers (40%) sprayed fungicides and insecticides five times per season, followed by six applications (30%). Twenty percent of farmers sprayed eight times per season (Fig. 5). Rates of fungicides and insecticides were according to manufacturers' instructions (Appendix V).

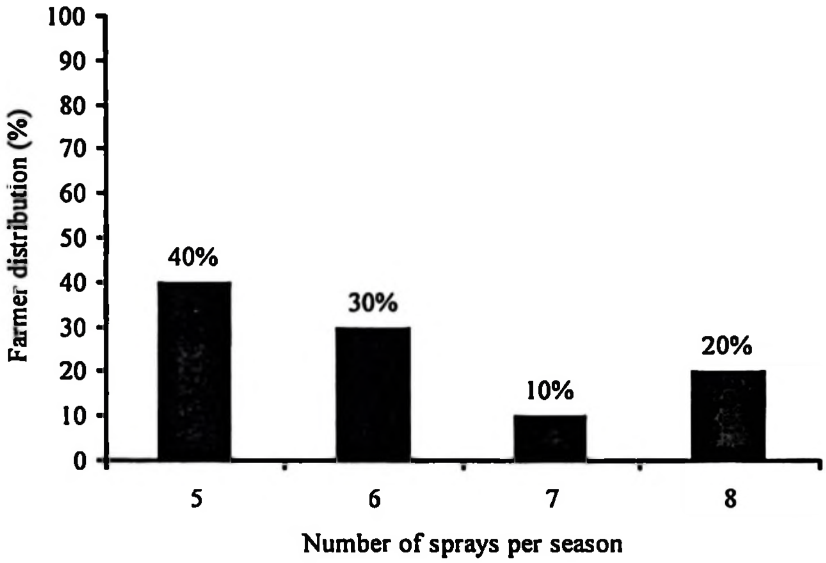

Figure 5: Farmers' distribution on total number of insecticides and fungicides application during August - December 2006 tomato growing season

4.1.1.3 Fertilizer use

Results (Fig. 6) indicate that Di-ammonium phosphate (DAP) was applied as basal and topdressing by 20% and 30% of farmers, respectively. All farmers applied nitrogen fertilizers. Of which, Urea was used by 70% of farmers, while 40% of farmers used SA and CAN, respectively. Fifty percent of the farmers used the foliar applied fertilizer Mult K.

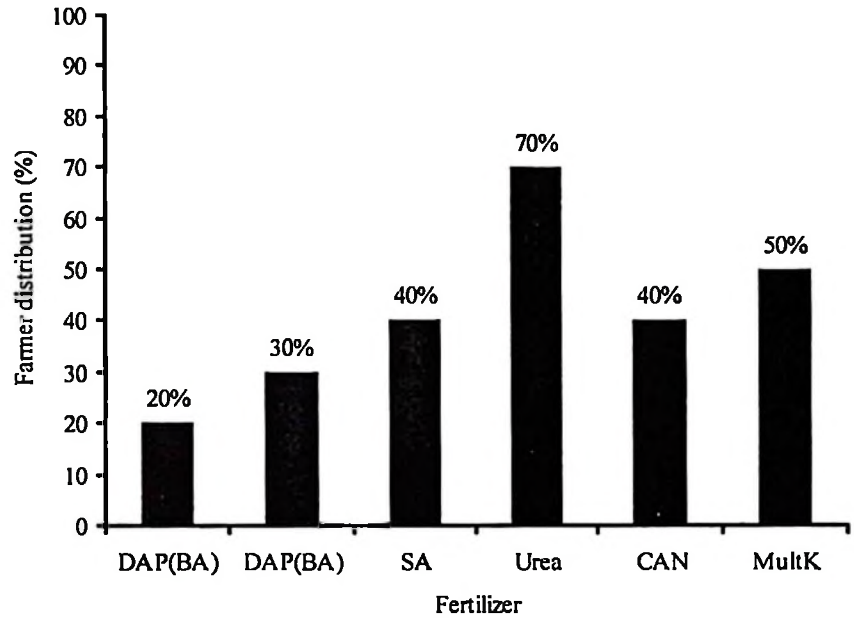

Figure 6: Farmers' distribution on fertilizer used during August - December 2006 tomato growing season

4.1.2 Tomato pests

4.1.2.1 Weeds

4.1.2.1.1 Weed counts and biomass

Results (Table 3a) show significant differences ($P \leq 0.05$) on weed counts among fields at two weeks after transplanting. Significantly higher sedge counts were recorded in four out of five fields at Mlali, while no single sedge was observed in all five Kipera fields and in one mulched field (M3) at Mlali. Grass weed (*Oryza* spp.) counts were significantly higher in K5 and M1 fields at Kipera and Mlali villages, respectively, than in other fields. Among broadleaf weeds observed (Table 3a), *Lactuca* spp. counts were statistically significant higher in one and two Kipera and Mlali fields, respectively. *Amaranthus* spp had significantly higher counts which were recorded in two fields at Mlali village out of five field surveyed; *Ageratum conyzoides* and *Argemone mexicana* counts were significantly higher in two Mlali and Kipera fields each, repectively; and only one field at Mlali village had significantly higher *Desmodium* spp. Moreover, mean sedge count was higher compared to other weeds observed.

Significant differences ($P \leq 0.05$) in weeds dry biomass were recorded at two weeks after transplanting among farmers' fields at Kipera and Mlali villages (Table 3b).Significantly higher sedge dry biomass were recorded in four out of five fields at Mlali, while none was recorded in all five Kipera fields. Significant higher *Oryza* spp. dry biomass was recorded in two out of fields at Mlali. Among broadleaf weeds *Ageratum conyzoides* and *Argemone mexicana* dry biomass were significantly higher in only two Mlali and Kiperas' fields each. Significantly higher *Desmodium* spp dry biomass was recorded at only one Mlali field. No significant differences on *Amaranthus* spp dry biomass were recorded among fields at both villages.

Table 3a: Weed count per m^2 two weeks after transplanting in Mlali and Kipera tomato grower fields during August - December 2006/07 season

Farmer Field	Sedge	Grassy weeds	Broadleaf weeds				
Farmer field	*Cyperus* spp.	*Oryza* spp.	*Lactuca* spp.	*Amaranthus* spp.	*Ageratum conyzoides*	*Argemone mexicana*	*Desmodium* spp.
K1	0.0b	0.0b	96.0b	0.0c	22.4bc	19.2ab	0.0b
K2	0.0b	6.4b	0.0b	12.8bc	28.8bc	28.8a	0.0b
K3	0.0b	0.0b	6.4b	0.0c	0.0c	0.0b	0.0b
K4	0.0b	0.0b	0.0b	0.0c	0.0c	0.0b	0.0b
K5	0.0b	0.0b	284.8a	0.0c	16.0bc	0.0b	0.0b
Sub mean	0.0	1.3	77.4	2.7	13.4	9.6	0.0
M1	566.4a	44.8a	163.2ab	25.6bc	41.6ab	0.0b	0.0b
M2	624.0a	38.4a	0.0b	0.0c	102.4a	0.0b	35.2a
M3	0.0b	0.0b	0.0b	0.0c	0.0c	0.0b	0.0b
M4	598.4a	0.0b	105.6ab	67.2a	0.0c	0.0b	0.0b
M5	624.0a	0.0b	32.0b	54.4ab	0.0c	0.0b	0.0b
Sub mean	482.7	16.6	60.2	29.4	28.7	0.0	7.0
Grand	241.3	9.0	68.8	16.0	21.1	4.8	3.5
SE	1.5	1.2	3.2	1.6	1.8	1.1	0.7

Means within the same column followed by the same letter(s) are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test (DMRT). K1 - K5 = Kipera farmers' fields, M1 - M5 = Mlali farmers' fields

Table 3b: Weed dry biomass (gm⁻²) two weeks after transplanting

Farmer Field	Sedge	Grassy weeds	Broadleaf weeds				
	Cyperus spp.	*Oryza* spp.	*Lactuca* spp.	*Amaranthus* spp.	*Ageratum conyzoides*	*Argemone mexicana*	*Desmodium* spp.
K1	0.0b	0.0b	12.8b	0.0	3.5b	2.9ab	0.0b
K2	0.0b	1.9b	0.0b	4.2	4.5ab	5.8a	0.0b
K3	0.0b	0.0b	1.0b	0.0	0.0b	0.0b	0.0b
K4	0.0b	0.0b	0.0b	0.0	0.0b	0.0b	0.0b
K5	0.0b	0.0b	39.7a	0.0	2.2b	0.0b	0.0b
Sub mean	0.0	0.6	10.7	0.9	2.1	5.7	0.0
M1	52.5a	6.1ab	22.4ab	7.7	3.5b	0.0b	0.0b
M2	58.9a	8.0a	0.0b	0.0	9.0a	0.0b	3.8a
M3	0.0b	0.0b	0.0b	0.0	0.0b	0.0b	0.0b
M4	57.3a	0.0b	15.0b	8.3	0.0b	0.0b	0.0b
M5	47.7a	0.0b	4.5b	6.4	0.0b	0.0b	0.0b
Sub mean	43.3	2.8	8.6	4.7	2.5	0.0	0.8
Grand	21.6	1.6	9.5	2.7	2.3	0.9	0.4
SE	4.9	1.8	7.8	3.1	1.7	1.6	0.5

Means within the same column followed by the same letter(s) are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test (DMRT). K1 - K5 = Kipera farmers' fields, M1- M5 = Mlali farmers' fields

Results (Table 3c) show significant differences ($P \leq 0.05$) on weed counts at four weeks after transplanting among fields. Significantly higher sedge count was recorded in only one Mlali field and no single sedge was observed in Kipera fields. In case of broadleaf weeds, significantly higher counts for *Lactuca* spp and *Argemone mexicana* were recorded in only two Kipera fields and none in other fields, while *Desmodium* spp. had significantly higher count in single field at Mlali. Generally, sedge mean populations were the highest among weeds observed and Mlali fields had the highest weed infestations (Table 3c).

At four weeks after transplanting significantly higher sedge biomass was recorded in one Mlali field than in others (Table 3d). In case of broadleaf weeds, significantly higher biomass for *Lactuca* spp and *Argemone mexicana* were recorded in two Kipera fields only, while *Desmodium* spp. had significantly higher biomass in one Mlalis' field. The overall weed means biomass was higher at two weeks after transplanting than at four weeks after transplanting.

Table 3c: Weed counts per m^2 four weeks after transplanting

Farmer Field	Sedge	Broadleaf weeds			
	Cyperus spp.	*Lactuca* spp	*Amaranthus* spp.	*Argemone mexicana*	*Desmodium* spp.
K1	0.0d	0.0b	0.0b	28.8a	0.0b
K2	0.0d	0.0b	0.0b	35.2a	0.0b
K3	0.0d	16.0a	0.0b	0.0b	0.0b
K4	0.0d	16.0a	0.0b	0.0b	0.0b
K5	0.0d	0.0b	0.0b	0.0b	0.0b
Sbu mean	0.0	6.4	0.0	12.8	0.0
M1	96.0c	0.0b	28.8a	0.0b	0.0b
M2	137.6b	0.0b	0.0b	0.0b	64.0a
M3	48.0c	0.0b	0.0b	0.0b	0.0b
M4	560.0a	0.0b	0.0b	0.0b	0.0b
M5	211.2b	0.0b	0.0b	0.0b	0.0b
Sub mean	210.6	0.0	5.8	0.0	10.8
Grand mean	105.3	3.2	2.9	6.4	6.4
SE	1.5	0.8	0.8	1.2	1.3

Means within the same column followed by the same letter(s) are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test (DMRT). K1 - K5 = Kipera Farmers' fields, M1 - M5 = Mlali Farmers' fields

Table 3d: Weed dry biomass (gm^{-2}) four weeks after transplanting

Farmer Field	Sedge (gm^{-2})	Broadleaf weeds (gm^{-2})			
	Cyperus spp.	*Lactuca* spp	*Amaranthus* spp.	*Argemone mexicana*	*Desmodium* spp.
K1	0.0d	0.0b	0.0b	1.3ab	0.0b
K2	0.0d	0.0b	0.0b	1.6a	0.0b
K3	0.0d	1.3a	0.0b	0.0b	0.0b
K4	0.0d	1.3a	0.0b	0.0b	0.0b
K5	0.0d	0.0b	0.0b	0.0b	0.0b
Sub mean	0.0	0.52	0.0	0.58	0.0
M1	9.3c	0.0b	2.0a	0.0b	0.0b
M2	9.9c	0.0b	0.0b	0.0b	2.9a
M3	5.4c	0.0b	0.0b	0.0b	0.0b
M4	49.6a	0.0b	0.0b	0.0b	0.0b
M5	16.6b	0.0b	0.0b	0.0b	0.0b
Sub mean	18.2	0.0	0.4	0.0	0.6
Grand mean	9.1	0.3	0.3	0.3	0.3
SE	2.0	0.4	0.7	0.4	0.9

Means within the same column followed by the same letter(s) are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test (DMRT). K1 - K5 = Kipera farmers' fields, M1- M5 = Mlali farmers' fields

4.1.2.2 Insect pests

Results (Table 4) indicated significant ($P \leq 0.05$) differences in insect pests' population among tomato fields. Whitefly colony counts ranged from 0 to 4.4 per plant and the overall fields mean count was one colony per plant. Significantly higher whitefly colony counts were observed in M4 field at Mlali than in other fields. Fifty percent of fields had significantly higher thrip counts per plant whereby 30% and 20% fields were at Mlali and Kipera, respctively. The number of thrips per 25 flowers was significantly higher in one field each at Kipera and Mlali villages, ranging from 0.2 - 0.4 thrips per 5 flowers than in the other eight fields. Aphid incidence was significantly higher in one field at Kipera and two fields at Mlali out of ten fields. The Kipera field had 56% aphid infestation more than Mlali field. Furthermore, significantly lower aphid incidences were observed at Kipera and Mlali villages by 30% and 10%, respectively (Table 4). Leaf miner incidence was significantly higher in one field at Kipera and significantly lower in two fields at Kipera and one field at Mlali than in other. Generally, the overall mean for leaf miner incidence was higher compared to other insect pests' incidence and population.

Table 4: Mean number of insect pests per plant in Kipera and Mlali tomato fields

Farmer Field	Whitefly colonies number/ plant	Thrips/ plant	Thrips/ 5 first flowers	Boll-worm (larva)/plant	Incidence (%)	
					Aphids	Leaf miner
K1	1.0ab	0.4ab	0.4a	0.2b	36.0bc	56.0bc
K2	1.0ab	0.6ab	0.0b	0.0b	64.0a	20.0cde
K3	0.0b	0.0b	0.0b	0.0b	8.0d	12.0f
K4	0.0b	0.0b	0.0b	0.0b	8.0d	20.0def
K5	0.0b	0.0b	0.0b	0.8a	16.0cd	100.0a
Sub mean	0.4	0.2	0.1	0.2	26.4	41.6
M1	0.4b	0.0b	0.0b	0.0b	28.0bcd	40.0cd
M2	1.0ab	0.2ab	0.2ab	0.0b	32.0bc	12.0ef
M3	0.2b	1.0a	0.0b	0.0b	36.0abc	80.0b
M4	4.4a	0.4ab	0.0b	0.0b	32.0bc	64.0bc
M5	0.0b	0.0b	0.0b	0.2b	52.0ab	68.0bc
Sub mean	1.2	0.5	0.04	0.04	36.0	51.0
Grand Mean	1.0	0.8	0.8	0.8	30.1	44.0
SE	0.1	0.1	0.01	0.03	6.3	5.0

Means within the same column followed by the same letter(s) are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test (DMRT). K1 - K5 = Kipera farmers' fields, M1 - M5 = Mlali farmers' fields

4.1.2.3 Disease severity

Results (Table 5) indicated significant ($P \leq 0.05$) differences on disease severity among tomato fields. No significant difference in late blight severity was observed among the fields. At Kipera village there was significantly higher early blight severity in K2 and septoria leaf spot severity in K1, K2 and K5 fields. Of the three diseases observed, septoria leaf spot accounted for 73% and 34% disease severity compared to early blight and late blight, respectively.

Table 5: Means of tomato disease rating in Kipera and Mali tomato fields

Farmer Field	Disease score (1 - 4)		
	Early blight	Late blight	Septoria leaf spot
K1	1.0b	2.0abc	3.0a
K2	3.0a	2.0abc	3.0a
K3	1.0b	1.0c	2.0b
K4	1.0b	1.0c	2.0b
K5	1.0b	3.0a	3.0a
Sub mean	1.4	1.8	2.6
M1	1.0b	2.0abc	2.0b
M2	1.0b	2.0abc	2.0b
M3	1.0b	2.0abc	2.0b
M4	1.0b	2.0abc	2.0b
M5	1.0b	3.0a	2.0b
Sub mean	1.0	2.2	2.0
Grand mean	1.2	1.5	2.0
SE	0.1	0.3	0.3

Means within the same column followed by the same letter(s) are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test (DMRT). K1 - K5 = Kipera Farmers' fields, M1- M5 = Mlali Farmers' fields. Disease rating: 1 = 0%, 2 = ≤ 10%, 3 = 10 - 50%, 4 = ≥ 50%

4.1.2.4 Incidence of nematode infection

Nematode infestation was statistically significant higher in three Mlali fields and in one Kipera field among the surveyed fields (Table 6). The incidences were variable, ranging from 20% - 100% of the plants sampled at Mlali and 20% - 60% of the plants sampled at Kipera.

Table 6: Nematode infection incidence distribution at Kipera and Mlali farmers' field

Farmers field	K1	K2	K3	K4	K5	M1	M2	M3	M4	M5
Incidence (%)	0b	20b	60a	0b	0b	100a	40ab	20b	20b	100a
Sub mean			16					56		

SE = 7, K1 - K5 = Kipera Farmers' fields, M1- M5 = Mlali Farmers' fields

4.1.3 Beneficial insects

Results (Table 7) indicated significant ($P \leq 0.05$) differences in the number of beneficial insects among fields. Significantly higher butterfly counts were recorded in K1and K5 fields while, honey bees' counts were significantly higher in K1 and K2 fields at Kipera village and M2 field at Mlali village. Stink bug population was significantly higher in K2 field and lower in K4 field. There was significant difference on spider counts among fields with higher significant difference in spider count in K5 field and lower in K1, K3, and K4. The overall mean count for stink bug was higher than that for butterfly, bees and spider by 60% each.

Table 7: Mean number of beneficial insects at Kipera and Mlali farmers' tomato fields

Farmer Field	Butterfly	Bees	Spider	Stink bugs
K1	1.4a	0.8a	0.0c	2.0ab
K2	0.4bc	0.6a	1.0abc	4.2a
K3	0.2bc	0.0b	0.0c	1.0cd
K4	0.0c	0.0b	0.0c	0.0d
K5	1.0ab	0.0b	2.0a	3.2abc
Sub mean	0.6	0.3	0.6	2.1
M1	0.2bc	0.0b	1.2ab	2.6bc
M2	0.4bc	0.4ab	1.0abc	2.4abc
M3	0.0c	0.0b	0.2bc	3.4ab
M4	0.0c	0.0b	1.0abc	2.0abc
M5	0.2bc	0.0b	1.0abc	3.0ab
Sub mean	0.2	0.1	1.0	2.7
Grand mean	1.0	1.0	1.0	1.6
SE	0.1	0.1	0.2	0.2

Means within the same column followed by the same letter(s) are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test (DMRT). K1 - K5 = Kipera farmers' fields, M1- M5 = Mlali farmers' fields

4.1.4 Tomato total yields (TY)

Results (Table 8a) indicate significant ($P \leq 0.05$) differences in total yield among farmers' fields. Among tomato fields surveyed at Kipera, 60% had significantly the lowest total yield ranging from 2.3 - 3.2 t/ha while, the lowest total yield ranging from 4.4 - 5.0 t/ha were recorded in 40% of Mlali fields. Of the highest total recorded between the two villages, Mlali recorded 83.3% higher total yield than Kipera. The overall range of the total was 3.2 - 11.0 t/ha.

4.1.4.1 Clean marketable Fruits

Total clean marketable fruits were significantly ($P \leq 0.05$) different among surveyed fields. Significantly highest clean marketable fruits were recorded in 10% of fields at Mlali village and lower clean marketable fruits were observed in 40% and 20% from Kipera and Mlali fields, respectively, (Table 8a).

Table 8a: Total tomato yields in farmers' fields during August - December 2006 growing season at Kipera and Mlali villages

Farmer Field	TY $t.ha^{-1}$	CMF $t.ha^{-1}$	TPDF $t.ha^{-1}$	TIDF $t.ha^{-1}$	TDDF $t.ha^{-1}$
K1	2.3e	1.5e	0.4de	0.2	0.2a
K2	3.3de	1.9de	0.6cd	0.9	0.6bc
K3	5.1cd	3.2cd	1.6a	0.5	0.3cd
K4	6.6bc	5.9b	0.5de	0.3	0.4bcd
K5	3.2de	3.0cde	0.1e	0.0	0.5bcd
Sub mean	4.1	3.1	0.5	0.4	0.4
M1	5.0cd	3.6c	0.4de	0.2	0.5bcd
M2	11.0a	8.6a	0.9bc	0.0	1.3a
M3	8.2b	6.7b	0.1e	0.1	1.4a
M4	7.9b	5.6b	1.1b	0.3	0.9b
M5	4.4d	2.4cde	0.9bc	0.5	0.6bc
Su mean	5.3	5.4	0.7	0.2	1.0
Grand mean	5.7	4.2	0.7	0.3	0.7
SE	0.6	0.5	0.1	0.1	0.1

Means within the same column followed by the same letter(s) are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test (DMRT). K1 - K5 = Kipera farmers' fields, M1 - M5 = Mlali farmers' fields, TY = total yield, CMF = clean marketable fruits, TPDF = total physiologically damaged fruit(s), TIDF = total insect damaged fruit(s), TDDF = total disease damaged fruit(s)

4.1.4.2 Physiologically damaged fruits

There were significantly ($P \leq 0.05$) differences in total physiologically damaged fruit(s) number and weight among the fields. The highest number and fresh weight of total physiologically damaged fruit(s) was recorded in Kipera fields accounting for 10% of all fields surveyed, however, other fields did not differ significantly. The mean physiologically damaged fruits ranged from 1.4 - 31.3% of total weight recorded. Fruits damage due to sunny scotch was most common compared to other factors.

Table 8b: Physiologically-damaged fruits during growing season August - December 2006 in farmers' fields at Kipera and Mlali villages

Farmer Field	Counts of physiologically damaged fruit x $10^4 ha^{-1}$				TPDF $t.ha^{-1}$	TPDF %
	BER	GC	SS	TPDF		
K1	1.8	1.8cd	2.6bcd	6.2cde	0.4de	17.3
K2	4.0	8.4a	0.0d	12.3bc	0.6cd	17.3
K3	0.2	1.3cd	18.0a	21.1a	1.6a	31.3
K4	2.6	3.1bc	2.6bcd	8.4b-e	0.5de	7.6
K5	0.9	1.3cd	0.4cd	2.6e	0.1e	3.9
Sub mean	1.9	3.2	4.7	10.1	0.6	17.5
M1	1.3	1.3cd	2.6bcd	5.3de	0.4de	7.1
M2	0.2	3.5bc	2.2bcd	5.9bcd	0.9bc	8.1
M3	0.4	0.0d	1.3cd	1.8e	0.1e	1.4
M4	2.6	4.4b	6.2b	13.2b	1.1b	13.7
M5	3.5	1.8cd	4.4bc	9.7bcd	0.9bc	20.7
Sub mean	1.4	2.0	2.3	7.2	0.7	10.2
Grand mean	2.6	2.7	4.1	9.1	0.7	13.8
SE	1.2	0.8	1.3	2.1	0.1	

Means within the same column followed by the same letter(s) are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test (DMRT). K1 - K5 = Kipera farmers' fields, M1 - M5 = Mlali farmers' fields, BER = blossom end rot, GC = growth cracked, SS = sunny scotch,

4.1.4.3 Insect damaged fruits

Results (Table 8c) indicate significant ($P \leq 0.05$) differences on number of insect damaged fruits by individual insects as well as by category. Significantly higher numbers of damaged fruits caused by stinkbugs, bollworms, thrips and whitefly damage were recorded in four, three, six and one field(s) out of ten fields, respectively. Moreover, mean number of fruits damaged by stinkbug was higher than other insect damages. Generally, number of total insect damage fruits was significantly higher in 40% of fields at Kipera and in 30% fields at Mlali. However, there was no significant difference on total insect damage fruits by weight among growers' fields. The overall yield loss due to insects damage ranged from 0 - 28% by weight.

Table 8c: Insect-damaged fruits during growing season August - December 2006 in farmers' fields at Kipera and Mlali villages

Farmer Field	Insect damaged fruit count ($x10^4ha^{-1}$)					TIDF	TIDF
	STB	BWM	THP	WFL	TIDF	$t.\ ha^{-1}$	%
K1	1.3bc	2.2ab	1.3ab	0.0b	4.8abc	0.2	11.6
K2	1.8abc	0.0c	0.9ab	0.0b	2.6abc	0.9	28.0
K3	4.4a	1.3abc	0.4b	1.3a	7.5a	0.5	10.2
K4	3.1ab	0.0c	2.2a	0.0b	5.3abc	0.3	4.8
K5	0.4bc	0.0c	0.0b	0.0b	0.4d	0.0	0.5
Sub mean	2.2	0.7	0.9	0.3	5.0	0.4	11.0
M1	0.9bc	0.9bc	0.9ab	0.0b	2.6abc	0.2	4.0
M2	0.0c	0.0c	0.0b	0.0b	0.0d	0.0	0.0
M3	0.0c	0.0c	0.9ab	0.4b	1.3cd	0.1	0.7
M4	1.3bc	2.6a	0.0b	0.0b	4.0a-d	0.3	4.3
M5	4.4a	0.9bc	0.9ab	0.0b	6.2ab	0.5	12.3
Sub mean	1.3	1.0	0.5	0.0	3.0	0.2	4.5
Grandmean	1.8	0.8	0.8	0.1	3.5	0.3	
SE	0.9	0.5	0.5	0.02	1.2	0.1	

Means within the same column followed by the same letter(s) are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test (DMRT). K1 - K5 = Kipera farmers' fields, M1 - M2 = Mlali farmers' fields, STB = stink bug, BWM = bollworm, THP = thrip, WFL = whitefly, TIDF = total insect damaged fruit(s)

4.1.4.4 Disease damaged fruits

Number and weights of damaged fruits by diseases were significantly ($P \leq 0.05$) different among tomato growers' fields. Early blight, late blight and fruit rot caused significantly higher number of damaged fruits in three, one and four field(s) out of ten, respectively. Thirty per cent (20%, Kipera; 10%, Mlali) of fields had significantly higher total disease damaged fruit(s) by count than the other fields. Twenty percent of fields at Mlali had significantly higher total disease damaged fruit(s) by weight than other fields. Generally, fruit rot contributed higher mean number of damaged fruits than other diseases to the total disease damage category. Overall yield loss caused by disease damage range was 5.8 - 19.0% (Table 8d).

Table 8d: Disease-damaged fruits during growing season August - December 2006 in farmers' fields at Kipera and Mlali villages

Farmer Field	Disease damaged fruits count ($x10^4ha^{-1}$)				TDDF ($t.ha^{-1}$)	TDDF (%)
	EB	LB	FR	TDDF		
K1	0.0b	0.0b	4.0d	4.0f	0.2d	6.7
K2	0.0b	0.0b	22.0ab	22.0abc	0.6bc	19.0
K3	0.4b	1.8a	10.1cd	12.3def	0.3cd	5.8
K4	0.9ab	0.0b	26.8a	27.7a	0.4bcd	6.5
K5	0.4b	0.0b	16.7bc	17.2b-e	0.5 bcd	15.6
Sub mean	0.3	0.2	15.9	18.6	0.4	10.7
M1	0.9ab	0.0b	9.2cd	10.1def	0.5bcd	9.7
M2	0.0b	0.0b	18.0abc	18.0bcd	1.3a	12.1
M3	0.0b	0.0b	23.8ab	23.8ab	1.4a	16.5
M4	0.4b	0.0b	12.3cd	12.8c-f	0.9b	11.7
M5	1.8a	0.0b	6.2d	7.9ef	0.6bcd	12.5
Sub mean	0.6	0.0	13.3	14.5	0.9	12.5
Grand mean	0.5	0.2	14.9	15.6	0.7	
SE	0.4	0.3	2.9	3.0	0.1	

Means within the same column followed by the same letter(s) are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test (DMRT). K1 - K5 = Kipera farmers' fields, M1 - M2 = Mlali farmers' fields, EB = early blight, LB = late blight, FR = fruit rot, TDDF = total disease damaged fruit(s)

4.2 Tomato pest population dynamics at On-station field experiment

4.2.1 Weed types, counts and dry biomass

The results (Table 9a) indicate significant ($P \leq 0.05$) differences in weed count and weight in all treatments at two weeks transplanting. Significantly lower *Cyperus* spp counts and dry biomass were observed in mulch and integrated pest management than in other treatments. Furthermore, mulch indicates significantly lowest counts and biomss of *Amaranthus* spp, and *Borrheavia* spp (broadleaf weeds) than other treatments. Moreover, mulch and grower standard had significantly lowest *Commellina* spp biomass than other treatments. The results (Table 9b) indicated significant ($P \leq 0.05$) differences in weed counts and dry biomass among treatments at Four weeks after transplanting. Integrated pest management had significantly lower *Cyperus* spp counts than other treatments. Check had higher counts and dry biomass for *Cyperus* spp and all broadleaf weeds observed than other treatments. Generally, *Cyperus* spp biomass was significantly lower in integrated pest management and mulch than other treatments.

Table 9a: Weed species counts (no. m^{-2}) and dry biomass (gm^{-2}) two weeks after transplanting

Treatment	Sedge		Broadleaf weeds					
	Cyperus spp.		*Boerrhavia* spp		*Amaranthus* spp.		*Commellina* spp	
	no.	wt (g)	no.	wt (g)	no.	wt (g)	no.	wt (g)
FTL	329.2a	32.8a	75.6a	7.8a	87.6a	7.0a	6.0	0.8a
MLH	3.6b	0.2b	0.0c	0.0c	0.0b	0.0b	2.4	0.0c
IPM	1.2b	1.3b	21.6b	1.0bc	73.6a	5.1a	4.8	0.6ab
TCI	320.2a	31.2a	76.8a	2.5ab	84.0a	5.0a	3.6	0.2bc
GRS	341.6a	36.2a	62.8a	3.4a	83.6a	5.6a	3.2	0.1c
TSI	400.4a	38.4a	56.8a	3.5a	84.8a	1.2a	4.4	0.4abc
CHK	345.4a	40.8a	53.6a	4.0a	79.6a	7.3a	2.8	0.3abc
MEAN	248.8	25.7	49.6	3.2	70.5	4.9	3.9	0.3
SE	49.1	5.2	0.3	1.7	0.2	1.0	0.2	0.2

Means within the same column followed by the same letter(s) within rows are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test. FTL = fertilizer, MLH = Mulch, IPM = Integrated pest management, TCI = tomato - cabbage intercrop, GRS = grower standard, CHK = check, TSI = tomato - spider plant intercrop.

Table 9b: Weed species counts (no.m^{-2}) and dry biomass (gm^{-2}) four weeks after transplanting

Treatment	Sedge		Broadleaf weeds					
	Cyperus spp.		*Boerrhavia* spp		*Amaranthus* spp		*Commellina* spp	
	no.	wt (g)	no.	wt (g)	no.	wt (g)	no.	wt (g)
FTL	314.2a	21.8b	53.2a	2.0b	47.6b	1.9b	0.8b	0.1b
MLH	40.6b	2.0c	1.6b	0.1b	4.4c	0.8b	0.0b	0.0b
IPM	9.6c	0.2c	30.8a	1.1b	52.0b	2.3b	0.4b	0.1b
TCI	306.0a	28.4b	31.2a	1.3b	46.0b	2.8b	1.6b	0.1b
GRS	318.8a	28.2b	34.0a	1.5b	49.6b	5.0b	5.6b	0.5b
TSI	359.4a	26.2b	29.2a	1.7b	32.4b	1.5b	0.8b	0.1b
CHK	416.0a	68.9a	54.8a	8.0a	95.2a	15.1a	9.6a	1.6a
MEAN	252.1	25.1	33.2	2.2	46.7	4.2	2.7	0.3
SE	48.4	6.0	0.4	0.7	0.3	0.3	0.2	0.3

Means within the same column followed by the same letter(s) within rows are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test. FTL = fertilizer, MLH = mulch, IPM = Integrated pest management, TCI = tomato-cabbage intercrop, GRS = grower standard, CHK = check, TSI = tomato-spider plant intercrop.

4.2.2 Effect of management practices on insect population dynamics

4.2.2.1 Population dynamics of aphid

There were significant (P $\leq$ 0.05) differences on aphid incidences among treatments (Fig.7). Significantly lowest aphid incidences were observed in grower standard and IPM than in other treatments throughout the season. The aphids' incidences in other treatments were significantly higher (80 - 100%) up to 21 days after transplanting. Beyond 21 days after transplanting, fertilizer and mulch maintained significantly higher aphid incidences while in check, tomato-cabbage intercrop and tomato-spider plant intercrop aphid incidences decreased. Furthermore, at 35 days after transplanting aphid incidence in check was similar to that in grower standard and IPM.

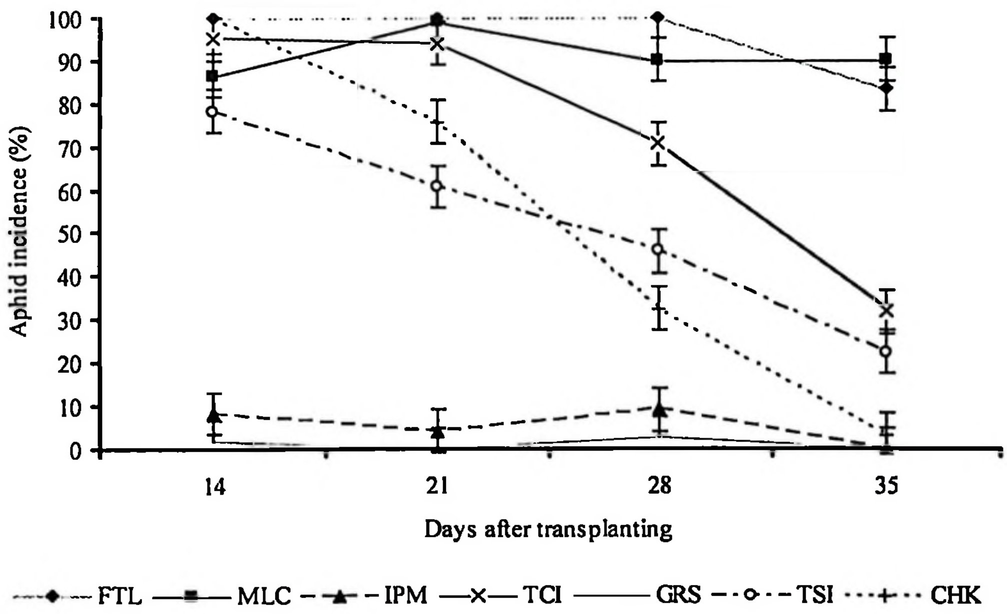

Figure 7: Incidence of aphid infestation (%) at on-station field experiment

4.2.2.2 Effect of management practices on leafminer incidence dynamics

Leaf miner incidences were significantly (P $\leq$ 0.05) different among treatments (Fig. 8). Throughout the season grower standard and IPM had significantly lowest leaf miner incidences and fertilizer, mulch, tomato-cabbage intercrop, tomato-spider plant intercrop and check had significantly highest leaf miner incidences. However at 35 days after transplanting tomato-cabbage intercrop and check had leaf miner incidences less than 80%.

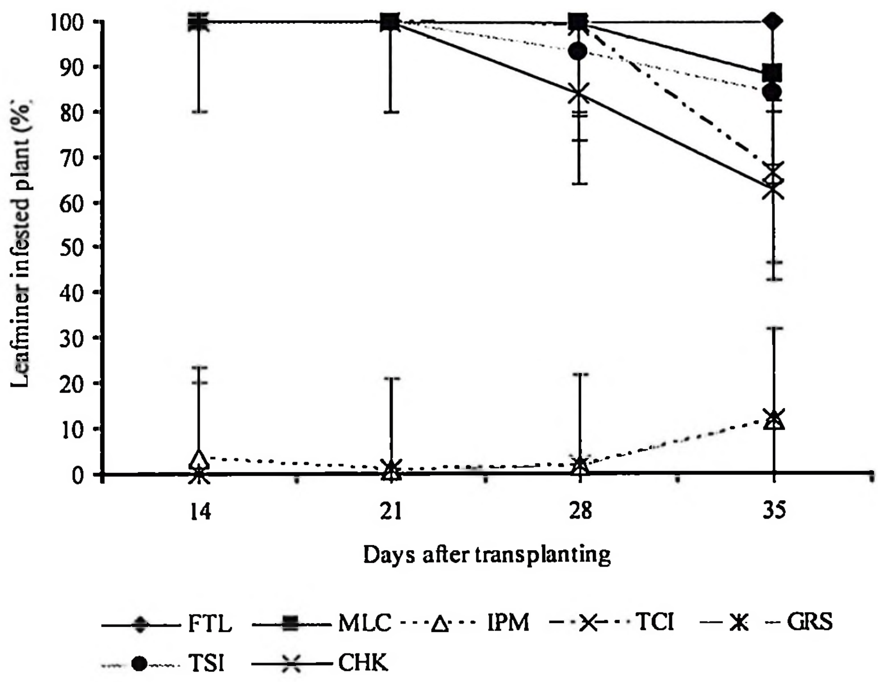

Figure 8: Incidence of plants infested by Leaf miner(s) (%)

4.2.2.3 Effect of management practices on whitefly colonies count

Results (Fig. 9) indicate significant differences ($P \leq 0.05$) on whitefly colony counts among the treatments. Beyond 14 days after transplanting grower standard, IPM, tomato-spider plant intercrop, tomato-cabbage intercrop and check had significantly lowest whitefly colony counts while, mulch and fertilizer treatments maintained significantly highest whitefly colony counts. The number of whitefly colonies in check significantly decreased gradually and became similar to grower from 28 days after transplanting.

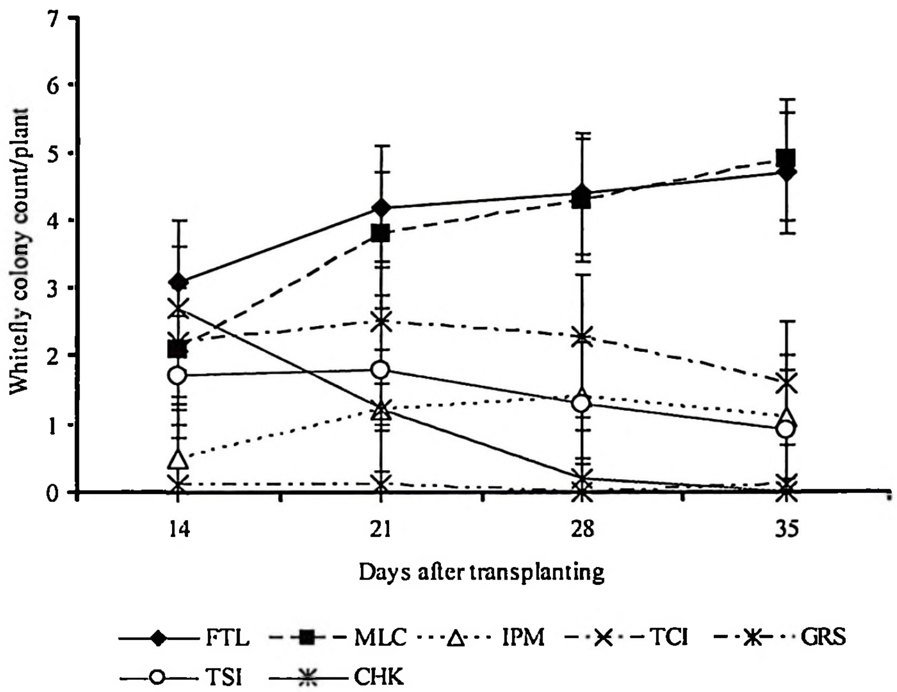

Figure 9: Mean whitefly colonies count

4.2.2.4 Effect of management practices on thrips population dynamics

Figure (10a) indicates that grower standard and IPM maintained significantly ($P \leq 0.05$) lowest thrip counts per plant throughout the season. At 21 days after transplanting, check had significantly highest thrips per plant counts and then decreased significantly to levels similar to grower standard and IPM. From 21 days after transplanting thrip per plant counts in fertilizer, mulch, tomato-spider plant intercrop and tomato-cabbage intercrop increased significantly up to 28 days after transplanting and then leveled off. Generally fertilizer and mulch maintained high thrips count per plant throughout the season. There was significantly ($P \leq 0.05$) decrease on thrips count per 5 flowers in check from 21 days after transplanting and leveled similar to grower. Beyond 28 days after transplanting thrips count per 5 flowers increased significantly in fertilizer and mulch treatments while other treatments had significantly lower counts (Fig. 10b).

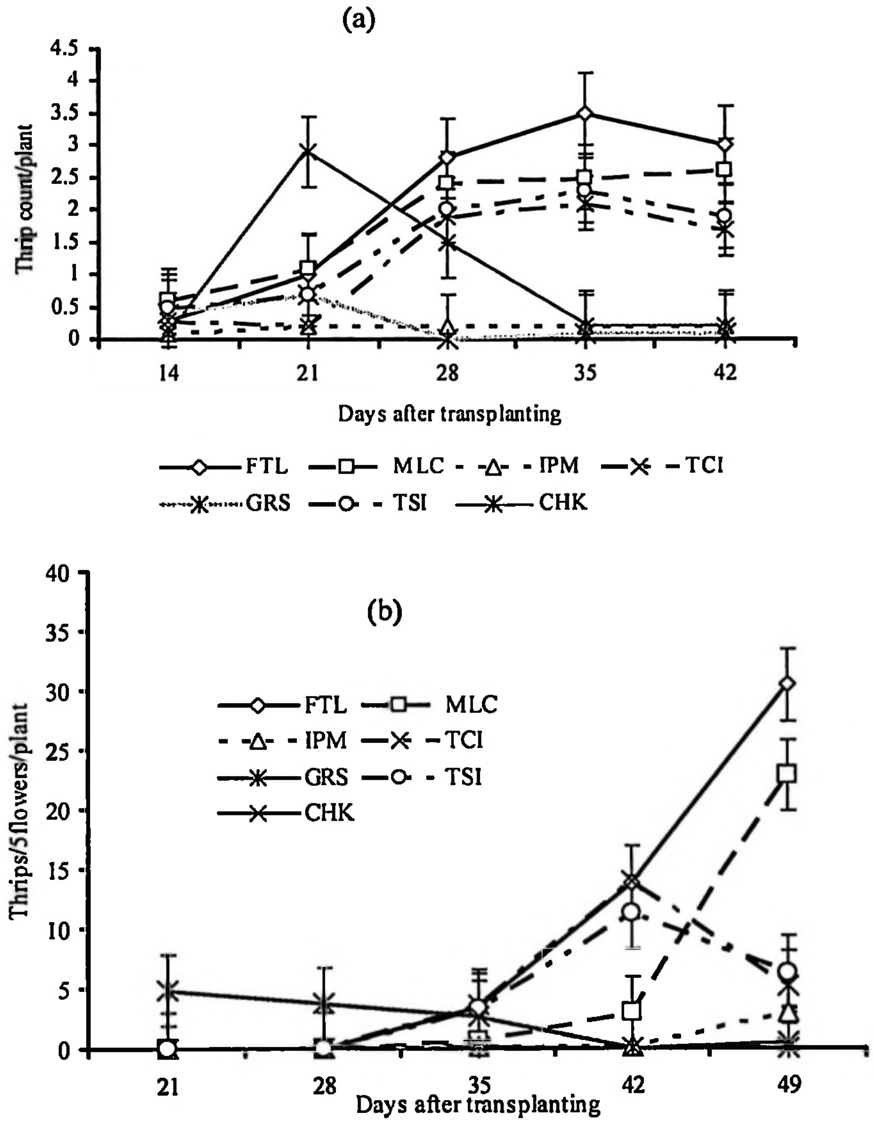

Figure 10: Thrips population on (a) leaves (b) 5 flowers

4.2.2.5 Effect of management practices on bollworm larva population dynamics

The number of bollworm larva increased significantly ($P \leq 0.05$) in all treatments throughout the season except in IPM and grower standard. However, tomato-spider plant intercrop had significantly higher larva count at 49 days after transplanting (Fig. 11).

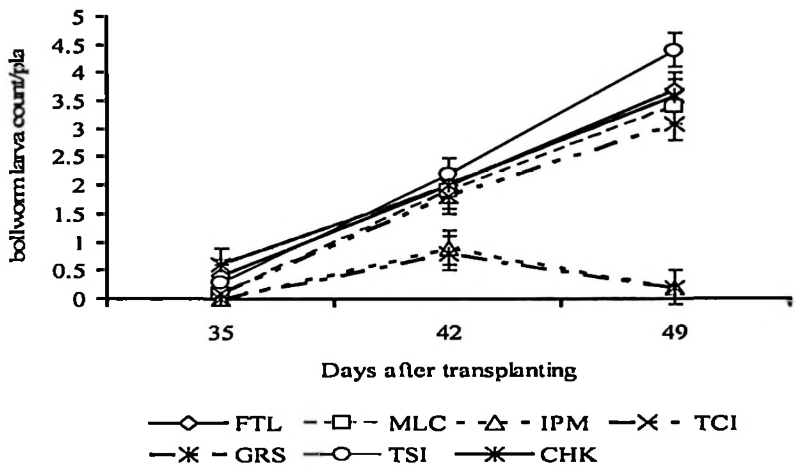

Figure 11: Population dynamics of bollworm larva

4.2.2.6 Effect of management practices on mites' population dynamics

Results (Fig. 12) indicate that mite populations were significantly highest for fertlizer and lowest for grower standard. However, in other treatments mite populations generally maintained between the two extremes.

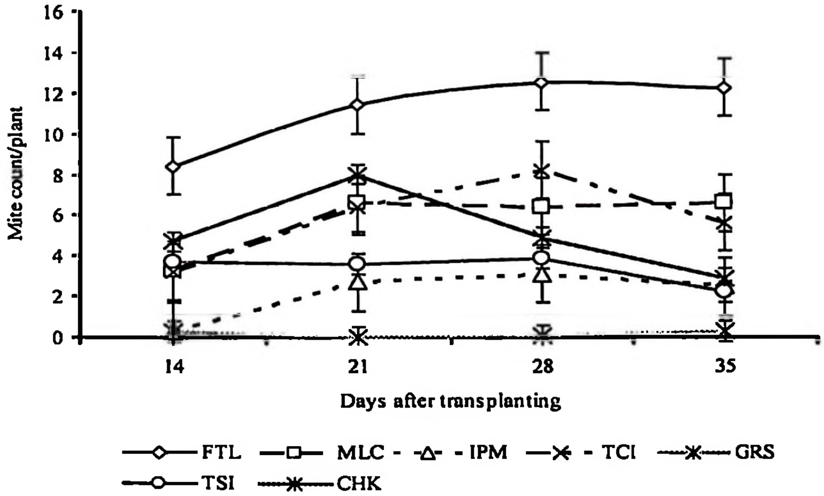

Figure 12: Population dynamics of mites

4.2.3 Diseases severity

Except for early blight diseases severity were significantly ($P \leq 0.05$) different among treatments. Late blight and septoria leaf spot severities were significantly ($P \leq 0.05$) higher in tomato-cabbage intercrop, tomato-spider plant intercrop and check than in other treatments. On the other hand, leaf curl incidence was significantly higher in tomato-cabbage intercrop than in other treatments. The overall mean disease severity was higher for septoria leaf spot than other fungal diseases (Table 10).

Table 10: Effects of tomato management practices on disease severity at On-station experiment

Treatment	Severity (1 - 4)			Incidence (%)
	EB	LB	SLS	LC
FTL	1.0	1.3c	1.7bc	5.7b
MLH	1.0	1.3c	1.5cd	5.8b
IPM	1.0	1.3bc	1.4cd	0.6c
TCI	1.2	1.6a	2.1a	12.4a
GRS	1.0	1.1c	1.2d	0.4c
TSI	1.1	1.6ab	2.1ab	1.9c
CHK	1.0	1.7a	2.4a	0.6c
MEAN	1.0	1.4	1.8	3.9
SE	0.4	0.6	0.9	6.3

Means within the same column followed by the same letter(s) within rows are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test. EB = Early blight, LB = Late blight, SLS = Septoria leaf spot, LC = leaf curl, FTL = Fertilizer, MLH = Mulch, IPM = Integrated pest management, TCI = tomato-cabbage intercrop, GRS = Grower standard, CHK = check, TSI = tomato-spider plant intercrop.

4.2.4 Effect of management practices on nematode infection incidence (%)

No significant ($P \geq 0.05$) difference in nematode infection incidences among treatments. All treatments had similar results in nematode infection incidences (Table 11).

Table 11: Effect of management practices on nematode infection incidence (%)

Treatment	Infected plants (%)
FTL	38.2
MLH	39.9
IPM	21.7
TCI	32.5
GRS	26.6
TSI	47.7
CHK	29.4
Mean	32.7
SE	6.6

Means within the same column followed by the same letter(s) are not significantly different at $P \leq 0.05$ according to Duncan Multiple Range Test (DMRT). FTL = fertilizer, MLH = mulch, IPM = Integrated pest management, TCI = tomato-cabbage intercrop, GRS = grower standard, CHK = check, TSI = tomato-spider plant intercrop.

4.2.5 Predator populations

4.2.5.1 Populations dynamic of spider, stink bug and bees

Spider population was significantly highest in tomato-spider plant intercrop and lowest in Grower standard, IPM and check throughout the season. Other treatments had populations between the two extremes (Fig.13). Considering individual species, tomato-spider plant intercrop, fertilizer, tomato-cabbage intercrop and mulch had significantly increased stinkbug populations throughout the season. Grower standard and IPM had significantly lower stink bug populations compared to other treatments (Fig.14). Bees' populations were significantly higher in check from 21 to 28 days after transplanting and decreased beyond that period. Beyond 28 days after transplanting, tomato-spider plant intercrop had significantly highest increase on bees' populations (Fig. 15).

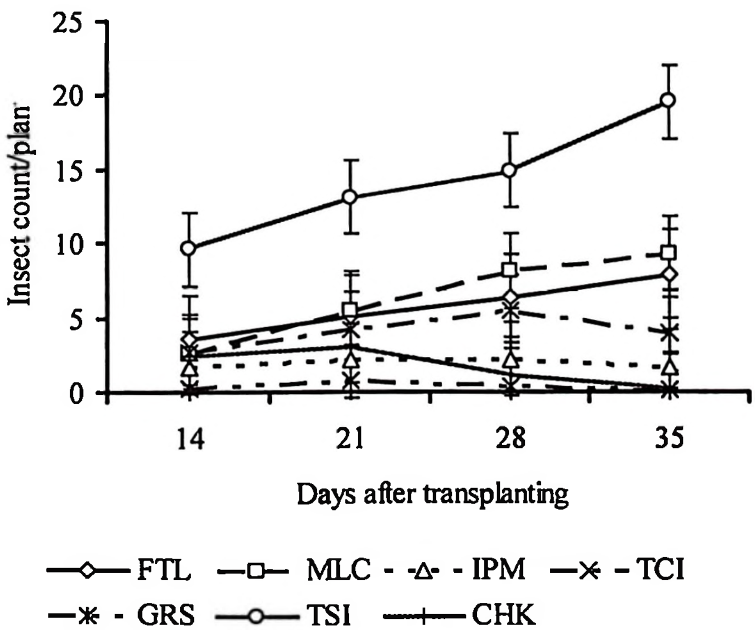

Figure 13: Dynamics of spider population

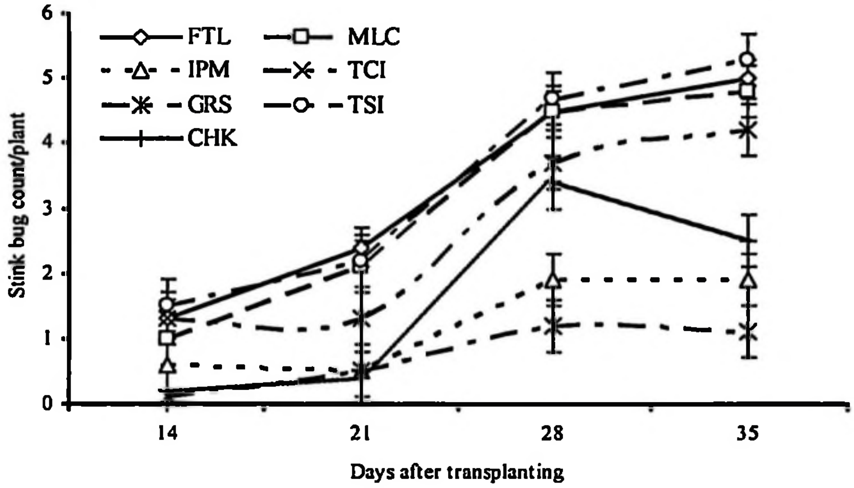

Figure14: Dynamics of stink bug population during Oct 2006 - Feb 2007 season at SUA Horticulture Unit, Morogoro, Tanzania

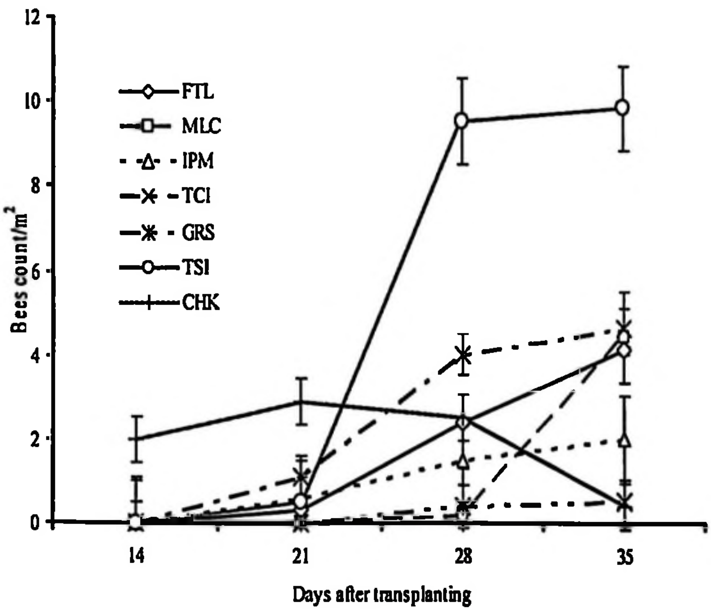

Figure 15: Dynamics of bees population

4.2.5.2 Populations dynamic of ladybird beetle and butterfly

Ladybird beetle and butterfly populations were significantly ($P \leq 0.05$) different from populations. Fertilizer, check and mulch had significantly higher ladybird beetles population than other treatments. Significantly higher butterfly populations were observed in tomato-spider plant intercrop and lower in grower standard and check (Table 12).

Table 12: Effect of management practices on butterfly and ladybird population dynamics

Treatment	Insect count	
	Ladybird beetle/plant	Butterfly/m^2
FTL	0.7a	0.9b
MLH	0.6ab	0.8b
IPM	0.2bc	0.6b
TCI	0.2bc	0.8b
GRS	0.1c	0.2c
TSI	0.9a	1.6a
CHK	0.1c	0.4c
Mean	0.3	0.8
SE	0.1	0.1

Means within the same column followed by the same letter(s) are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test (DMRT). FTL = fertilizer, MLH = mulch, IPM = Integrated pest management, TCI = tomato-cabbage intercrop, GRS = grower standard, CHK = check, TSI = tomato-spider plant intercrop.

4.2.6 Yield assessment

4.2.6.1 Yield components

There were significant ($P \leq 0.05$) differences in yield components among treatments. Fertilizer and mulch had higher number of branches than other treatments. While fertilizer and grower standard had significantly higher number of clusters per plant, higher number of fruits per cluster was observed in mulch than in other treatments. Fruit sizes were significantly higher in mulch, grower standard, IPM and fertilizer, however, mulch had higher weight per fruit than other treatment. Generally, all yield components were significantly lowest in check (Table.13a).

Table 13a: Effect of management practices on yield components

Treatment	Yield components count per plant			Weight	Fruit	Cumulative yields	
	Branch	Cluster	Fruit/cluster	/Fruit (g)	size (1-5)	No.(x 0^4ha^{-1})	($t.ha^{-1}$)
FTL	11.2a	14.3a	4.0b	50.2b	1.8ab	19.4ab	0.8b
MLH	10.4a	8.6b	5.6a	64.0a	2.1a	22.1a	1.0a
IPM	6.3c	8.8b	3.0c	48.7b	1.8ab	16.0bc	0.6bc
TCI	5.2d	8.5b	3.0c	51.6b	1.5b	16.2b	0.6bc
GRS	7.6b	11.4ab	4.0b	50.4b	2.1a	13.7c	0.5c
TSI	5.6cd	8.3b	3.0c	52.7b	1.9ab	13.4c	0.5c
CHK	3.4e	4.2c	2.0d	46.1b	0.5c	3.8d	0.1d
Mean	7.1	9.2	3.5	52.0	1.7	14.9	0.6
SE±	0.4	1.1	0.2	3.8	0.2	1.5	0.1

Means within the same column followed by the same letter(s) within rows are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test. FTL = fertilizer, MLH = mulch, IPM = Integrated pest management, TCI = tomato-cabbage intercrop, GRS = grower standard, CHK = check, TSI = tomato-spider plant intercrop.

4.2.6 Total yields and categories

Total yield was significantly highest under mulched and lowest in control. Other treatments had total between the two extremes. Generally, mulch excelled other treatments in terms of effecting total yield and categories. The results also show the differences in fruit categories (Append. VI). In all treatment insect damaged fruit category (39 - 64%) outweighed other damage categories (5 - 30%) except for grower standard and IPM whose much damage were physiological damage (30 - 32%). Among the treatments check had the highest insect damaged fruits followed by tomato-cabbage intercrop and tomato-spider plant intercrop (47 - 49%). Moreover, insect damage category had low contribution to the fruits damage (5 - 9%) among all treatments (Fig. 16).

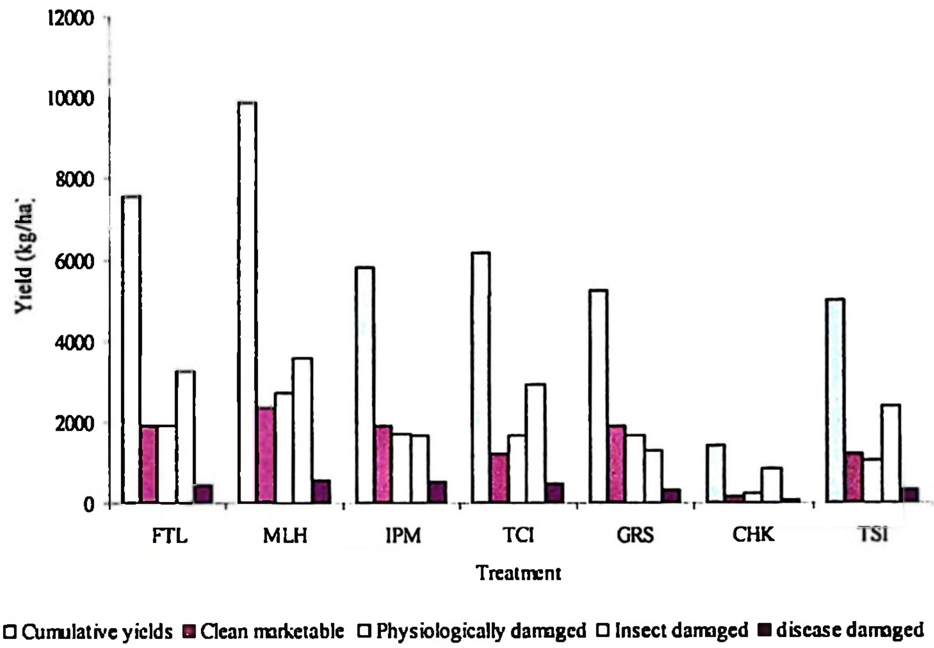

Figure 16: Total fruit yields and categories

4.2.6.1 Effect of management practices on clean marketable fruits

Grower standard, IPM, mulch and fertilizer treatments had significantly higher clean marketable fruit categories than other treatments and check had the lowest clean marketable fruits category (Table 13b).

Table 13b: Effect of management practices on clean marketable fruits

Treatment	Clean marketable fruits		
	No. ($x10^4ha^{-1}$)	Wt. ($t.ha^{-1}$)	(%)
FTL	3.4ab	1.9ab	25.2
MLH	3.9ab	2.4a	24.2
IPM	3.8ab	1.9ab	34.3
TCI	2.4b	1.2b	20.0
GRS	4.5a	1.9ab	36.6
TSI	2.4b	1.2b	24.3
CHK	0.4c	0.2c	14.3
Mean	3.0	1.5	26.0
SE	0.6	0.1	39.7

Means within the same column followed by the same letter(s) within rows are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test. FTL = fertilizer, MLH = mulch, IPM = Integrated pest management, TCI = tomato-cabbage intercrop, GRS = grower standard, CHK = check, TSI = tomato-spider plant intercrop.

4.2.6.2 Effect of management practices on fruit physiological damage

Results (Table 13c) indicate significant differences ($P \leq 0.05$) on various fruit physiological damages among treatments. Mulch had significantly high number of sunny scotched fruits followed by fertilizer than other treatments. Tomato-spider plant intercrop and check had lower number of fruits damage due to growth crack than other treatments. Check had significantly lower fruit number with blossom end rot than other treatments.

Table 13c: Effect of management practices on tomato fruit physiological damage

Treatment	Fruit count/m^2					
	SS	GC	BER	TPDF		
				(no. m^{-2})	(kgha^{-1})	(%)
FTL	3.0b	1.7ab	0.7a	5.4ab	190.8b	25.2
MLH	4.9a	2.1ab	0.3ab	7.3a	274.4a	27.8
IPM	1.9bc	3.0a	0.6a	4.5b	171.6b	29.5
TCI	1.6bcd	2.2ab	0.4ab	4.3b	165.3b	26.7
GRS	1.9bc	2.3ab	0.6a	4.7b	167.7b	31.9
TSI	1.4cd	1.2bc	0.6a	3.2b	105.5bc	21.1
CHK	0.2d	0.3c	0.1b	0.6c	25.6c	17.9
Mean	2.1	1.8	0.5	4.3	157.3	26.8
SE	0.5	0.4	0.1	0.7	28.2	

Means within the same column followed by the same letter(s) within rows are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test. FTL = fertilizer, MLH = mulch, IPM = Integrated pest management, TCI = tomato-cabbage intercrop, GRS = grower standard, CHK = check, TSI = tomato-spider plant intercrop, BER = blossom end rot, GC = growth crack, SS = sunny scotch, TPDF = total physiologically damaged fruits

4.2.6.3 Effect of management practices on fruits damaged by insect

Results (Table 13d) show that the number of fruits damaged by respective insect was significantly ($P \leq 0.05$) different among treatments. Number of fruits damaged by thrips was significantly lower in IPM, grower standard and check than in other treatments. Fertilizer and mulch had significantly higher number of stinkbug damaged fruits and lower for grower standard and check than for other treatments. Mulch, tomato-cabbage intercrop, fertilizer and tomato-spider plant intercrop had significantly higher number of fruits damaged by bollworm than other treatments; however, tomato-spider plant intercrop had low number of damaged fruits. Fertilizer had significantly higher number of fruits damage by whitefly than other treatments. Generally, Fertilizer, mulch, tomato-cabbage intercrop and tomato-spider plant intercrop had significantly higher number of total insect damaged fruits than other treatments.

Table 13d: Effect of management practices on ripe tomato fruits damaged by insect

Treatment	Fruit counts (no.m^{-2})				TIDF		
	THP	STB	BWM	WFL	no.m^{-2}	kgha^{-1}	%
FTL	2.1ab	3.4a	3.3a	0.5a	9.3a	325.3ab	43.0
MLH	2.9a	2.7ab	3.4a	0.4ab	8.9a	358.9a	36.3
IPM	1.5bc	1.7bc	1.7bc	0.2abc	5.1bc	165.3cd	28.4
TCI	2.4a	2.3b	3.0a	0.4ab	8.2a	291.7ab	47.1
GRS	0.9c	1.0cd	1.5bc	0.1bc	3.5cd	128.7d	24.5
TSI	2.1ab	2.2b	2.4ab	0.2abc	6.9ab	238.5bc	47.7
CHK	0.9c	0.6d	0.7c	0.0c	2.2d	84.2d	59.0
Mean	1.9	2.0	2.3	0.2	6.3	227.5	38.7
SE	0.3	0.4	0.4	0.1	0.9	29.6	

Means within the same column followed by the same letter(s) within rows are not ($P \geq 0.05$) different according to Duncan Multiple Range Test. FTL = fertilizer, MLH = mulch, IPM = Integrated pest management, TCI = tomato-cabbage intercrop, GRS = grower standard, CHK = check, TSI = tomato-spider plant intercrop, THP = thrip, BWM = bollworm, STB = stinkbug, WFL = whitefly, TIDF = total insect damaged fruit

4.2.6.4 Effect of management practices on fruits damaged by disease

There were significantly ($P \leq 0.05$) differences in the number of fruits damaged by respective disease and their category weight among treatments. Fruits damaged by early blight were significant higher in tomato-cabbage intercrop, fertilizer, IPM and mulch than in other treatments. Numbers of fruits damaged by late blight were higher in fertilizer, IPM, mulch, tomato-spider plant intercrop and tomato-cabbage intercrop than in grower standard and check. Numbers of fruits damaged by fruit rot was significantly higher in all treatments than in check. Furthermore, fruit rot had high contribution on disease damage fruit category in all treatments (Table 13e).

Table 13e: Effect of management practices on ripe tomato fruits damaged by disease

Treatment	Fruit counts/m^2			Total fruits		
	EB	LB	FR	no.m^{-2}	kgha^{-1}	%
FTL	0.3a	0.4a	0.6ab	1.3ab	441.8ab	5.8
MLH	0.2ab	0.3ab	1.0ab	1.5a	582.9a	5.9
IPM	0.2ab	0.3ab	1.3a	1.8a	515.3ab	8.9
TCI	0.3a	0.2ab	1.0ab	1.5a	499.6ab	8.1
GRS	0.1b	0.1b	0.9ab	1.1ab	316.1ab	6.0
CHK	0.1b	0.1b	0.1b	0.3b	72.1b	5.0
TSI	0.1b	0.3ab	0.7ab	1.1ab	316.5ab	5.0
Mean	0.2	0.2	0.8	1.2	39.2	6.8
SE	0.1	0.1	0.3	0.4	14.1	

Means within the same column followed by the same letter(s) within rows are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test. FTL = fertilizer, MLH = mulch, IPM = Integrated pest management, TCI = tomato-cabbage intercrop, GRS = grower standard, CHK = check, TSI = tomato-spider plant intercrop, EB = early blight, LB = late blight, FR = fruit rot and TF = Total fruits

4.3 On-station field experiment on the influence of spider plants on tomato insect pests and beneficial insects

4.3.1 Insect populations at vegetative stage

Insects' populations were significantly ($P \leq 0.05$) different among treatments during vegetative growth. Significantly higher thrips population was observed on tomato plants in tomato monocrop and tomato-spider plant intercrop treatments than in spider plant monocrop treatment On the other hand, spider plant monocrop treatment had significantly higher aphid and leaf miner incidences as well as stinkbug and spider populations than other treatments. Although incidence of aphids' did not differ significantly between tomato monocrop and tomato-spider plant intercrop; tomato monocrop had higher aphid incidence (Table 14).

Table 14: Mean insect populations at vegetative stage

Treatment	Insect pests			Beneficial insects	
	Count/plant	Incidence (%)		count/plant	
	Thrips	Aphid	Leafminer	bug	Spider
TSI	11.7 a	20.0b	13.3b	0.0b	0.3b
ToM	11.3 a	26.7b	13.3b	0.3b	0.0b
SM	0.0 b	91.7a	68.3a	3.3a	2.7a
Mean	7.7	46.1	31.7	1.2	1.0
SE	0.2	6.9	2.5	0.2	0.1

Means within the same column followed by the same letter(s) within rows are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test. TSI = tomato-spider plant intercrop, ToM = tomato monocrop, SM = spider plant monocrop

4.3.2 Insect populations at flowering stage

Results (Table 15) show significant ($P \leq 0.05$) differences on insect populations and incidences among treatments. Spider plant monocrop registered no single thrip per plant and thrip per 5 flowers than in other treatments. Highest thrips population was observed in tomato monocrop. No significant difference was observed on whitefly colonies counts in all treatments. On the other hand, spider plant monocrop showed highest aphid and leaf miner incidences as well as stinkbug and spiders count that proved statistically significant.

Table 15: Mean insect populations at flowering stage

Treatment	Insect pests					Beneficial insects	
	count/plant			Incidence (%)		count/plant	
	Thrip	Thrips/5flowers	WFC	Aphid	Leafminer	stinkbug	Spider
TSI	8.0a	15.0a	0.3	35.0b	50.0b	1.3b	1.7b
ToM	10.0a	18.0a	1.0	25.3b	38.3b	0.7b	0.7c
SM	0.0b	0.0b	1.3	91.7a	78.3a	4.3a	3.0a
Mean	5.9	11.1	0.9	50.7	55.6	2.1	1.8
SE	0.1	0.5	0.1	8.5	3.2	0.1	0.1

Means within the same column followed by the same letter(s) within rows are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test. WFC = whitefly colony, TSI = tomato-spider plant intercrop, ToM = tomato monocrop, SM = tomato monocrop

4.3.3 Insect populations at fruiting stage

The results (Table 16) indicate significant ($P \leq 0.05$) differences in insect populations among treatments. Counts of thrip per plant were significantly higher in tomato monocrop and tomato-spider plant intercrop, however, tomato monocrop had significantly higher counts of thrip per 5 flowers. Significantly higher bollworm, bug and spider counts as well as aphid and leaf miner incidences were observed in tomato monocrop than in other treatments.

Table 16: Mean insect populations at fruiting stage

Treatment	Insect pests						Beneficial insects	
	count/plant				Incidence (%)		count/plant	
	Thrip	Thrips/ /5flower	WFC	Bollworm	Aphid	Leafminer	Stinkbug	Spider
TSI	2.0a	1.7b	0.3a	1.3ab	8.3b	53.3b	0.3b	1.7ab
ToM	4.0a	5.7a	1.0a	0.0b	12.7b	43.3b	1.0b	0.7b
SM	0.0b	0.0b	0.7a	3.0a	96.7a	86.7a	3.3a	2.3a
Mean	2.0	2.4	0.7	1.4	39.2	61.1	1.3	1.4
SE	0.4	0.6	0.2	0.2	0.9	3.7	0.0	0.2

Means within the same column followed by the same letter(s) within rows are not significantly ($P \geq 0.05$) different according to Duncan Multiple Range Test. WFC = Whitefly colony, TSI = tomato-spider plant intercrop, ToM = tomato monocrop, SM = spider plant monocrop

CHAPTER FIVE

5.0 DISCUSSION

5.1 Farmers tomato production conditions

In Morogoro, tomato production is carried out in two main phases, it is grown as a sole crop after the main rain season following paddy in lowlands to take advantage of residual moisture and later in the dry season under irrigation. Farmers in the villages at Kipera and Mlali where the study was conducted elucidated that, seeds, pesticides (insecticides and fungicides) and inorganic fertilizers were the most important inputs for tomato production. The study revealed that Cal J was the most popular variety grown by 50% of farmers, and the other two varieties, Tanya and Ornyx, were grown by fewer farmers. Most farmers (80%) depended on purchased seeds from agrochemical dealers rather than extraction from previous crop. The results concurred with baseline survey report whereby 71.8% growers were reported to purchase seeds from agrochemical retailer shops (Maerere *et al.*, 2006).

All growers used inorganic fertilizers for tomato production. Such fertilizers included di-ammonium phosphate (DAP), sulphate of ammonia (SA), urea, Calcium of ammonium nitrate (CAN) and multK. Similarly, Maerere *et al.* (2006) reported that 99% of tomato grower interviewers used inorganic fertilizers during previous season. Only 20% of tomato growers used di-ammonium phosphate (DAP) for basal application. The use of sulphate of ammonia (SA) and urea by 70% of tomato growers and DAP by 30% for top dressing two weeks after transplanting and other fertilizers such as calcium of ammonium nitrate (CAN) and foliar fertilizer mult K. implies that tomato growers understand the importance of fertilizers in tomato production and that they lack knowledge on essential plant nutrients.

5.2 Pests prevalence

Among pests, leaf miner (*Lilioryza* spp) and septoria leaf spot a fungal disease caused by *Septori lycopersic*, were ranked the most serious in both villages and *Cyperus* spp and *Argermone mexicana*, were ranked as the most serious weeds in Mlali and Kipera, respectively. The high number of *Argermone mexicana* in Kipera was attributed to weeding escape as the weed notorious late in the main crop season especially in maize fields (upland). Occurrence of high population of *Lactuca* spp. was due to fact that the weed is used as vegetable. The On-station field experiment also showed significantly higher *Cyperus* spp population in all unmulched except IPM plots at two weeks after transplanting compared to four weeks after transplanting. These significant high number of *Cyperus* spp in Mlali fields and all unmulched except IPM plots was attributed to surface irrigation, sprouting of high number of tubers exposed to soil surface during cultivation operations and low light competition with crop and other weeds early in the season. The results concur with the findings of Sibuga (2002) who reported high population of sedges in rice fields at lowland caused by wet conditions. Similarly, *Cyperus* spp ranked highest across Kipera and Mlali villages as a difficult weed pest affecting tomato production in the study area (Maerere *et al.,* 2006). Furthermore, low population of sedge population at four weeks after transplanting (after first weeding) was the evidence that, effective weed control strategies early in the season could free the crop from weed competition hence, good crop establishment. Lower population of most broadleaf weeds was probably due to low weed seed banks or allelopathic effect of sedges on germinating other weed seeds Drost and Doll (1980) reported inhibition of growth on some crops by yellow nutsedge tubers and leaves.

Leaf miner was recorded as the most important insect pest in farmers' tomato fields and at On-station field experiment accounting for 47% and 33% incidences, respectively, higher than aphids. This could be due to increased chances for infestation as attributed by bushy growth type of determinate tomato varieties which was accompanied by large leaf area and greater number of leaves offering food and oviposition site for the insect. The results are inconsistent with Maerere *et al.* (2006) who ranked American bollworm as serious insect pest, however, in terms of importance, aphids were considered as the most destructive insect pest of tomato and leaf miners were not mentioned at all. Fracknath (2005) demonstrated that infestation by leaf miner begins in lower leaves of the crop and proceeds through the middle leaves to those of the upper canopy. Other insect pests were thrips, whitefly and bollworm whose population did not exceed one per plant.

The survey conducted on disease severity in farmers' fields indicated that, of the three diseases observed, septoria leaf spot was the most serious disease accounting for 73% and 34% disease severity higher than early blight and late blight, respectively. However, tomato fields at Kipera had medium septoria leaf spot severity and Mlali had lower disease severity.

The on-station field experiment indicated that septoria leaf spot had 29% higher disease severity than other fungal diseases and therefore, septoria leaf spot was ranked as the most important disease. This could be due to the presence of disease inoculum in the soil and dispersal of pathogens by irrigation water through splash. The results are consistent with Ojiambo and Sherm (2005) in that Septoria leaf spot infections occur on leaves at all developmental stages of the crop due to presence of inoculum all season-long. Furthermore, bushy growth habit of the crop variety impairs the penetration of light thus, facilitated disease development. Similarly according to Elmer and Ferrandino (1995) and Ferrandino and Elmer (1996) studies in other Septoria pathosystems have documented the inhibition of spore germination in conditions of high light intensity. Inconsistently, according to interviewed tomato growers in the study area, tomato blight was ranked as the most destructive disease in tomato production (Maerere *et al.,* 2006). This was attributed by farmers' failure to distinguish disease symptoms. The study indicates the need for implementation of control tactics prior to disease development when determinate varieties are grown by providing support and surface cover to minimize contact of leaves with the soil.

Most farmers spray fungicides and insecticides 5 - 8 times per season. In order to control diseases and insect pests, the study showed that Dithane M45 and Karate are mostly used to control diseases and insect pests. According to Maerere *et al.* (2006) survey report farmers use insecticides (Karate) at least once up to 24 times per season and fungicides (Dithane M45) at least three times up to 12 times. Furthermore, the study showed that most tomato growers used more than one type of fungicides and only one type of insecticide during the season. This implies that tomato growers have a strong belief that insecticides and fungicides are the only solution for all their insect pest and disease problems. Moreover, many sprays per season implies require knowledge on chemical use to control pests based on scouting and monitoring of the respective pest. The implication of these findings is that farmers need knowledge on tomato production practices particularly on plant nutrition and pest management in order to realize high yield and good fruits quality.

The study showed that 70% of tomato farmers' fields surveyed were infected with nematodes. Of all fields surveyed in the villages, Mlali fields were all infected by nematodes constituting 50% while in Kipera fields only 20% of fields were infected. This was probably due to lack of crop free period between main season and off season crops such as rice rotation with tomato, furthermore, use of canals for surface irrigation could be the means for inoculum disseminations. The results concur with Nono-Womdim *et al.* (2002) who found that all tomato growing regions in Tanzania were infected by root-knot nematodes and 89% of samples collected were infected by *M. javanica* the most common and widespread nematode species associated with root-knot of tomatoes.

According to Netscher and Sikora (1990) extent of root-knot damage on vegetables is reduced when flooded rice is rotated with vegetables. Furthermore, he suggested that the uneven distribution of the pathogen population among the plots/fields and from season to season was the cause of the variation of disease incidence among cultivars and fields. On the other hand, management techniques showed no significant difference on nematode incidence, this could be due to even distribution of pathogen and that they have similar effects. According to farmers field results the study implies that tomato fields should be checked season after season on the incidence of nematode as the disease pathogens are disseminated by field operations as well as surface running water. This could allow appropriate control methods implementation before population buildup and dispersal to a large area.

5.3 Pest management strategies

In order to alleviate pest populations, different management strategies are employed. The study in farmers' fields indicated that 60% and 40% of farmers grow tomato under monocropping and intercropping with maize, respectively, and only 10% of farmers used rice straw for mulching. However, all tomato growers used insecticides and fungicides to control insect pests and diseases, respectively, and only hand hoe weeding was done to control weeds.

According to the results on weeds types and population at farmers' fields, all tomato fields at Mlali except where mulching was applied were dominated by nutsedges. Two weeks after transplanting, high nutsedge counts and biomass observed was attributed to high residue soil moisture which enhanced sprouting of fragmented tubers and ineffective control of sedge by hand hoe cultivation, due to food storage structures (tubers) that provide competitive advantage over other weeds as well as tomato plants early in the season. Similar results were observed in all treatments except in mulching and IPM treatments at On-station experiment. Similarly, Bewick, *et al.* (1995) and Holm *et al.* (1991) reported that nutsedges success as weeds in vegetable crops was due to presence of sedge tubers rapid and abundant reproduction, widespread distribution and difficult in control.

Low weed populations in mulched field at Mlali and at On-station field experiment was attributed to unfavourable conditions for seed germinations such as low temperatures, absence of sufficient O_2, and light and physical barrier provided by mulch. Findings by Rwezaura *et al.* (2005) indicated that organic mulches were effective in controlling the weeds by preventing the weed seeds from sprouting and germinating. However, low nutsedge population in IPM treatment was attributed to killing of the actively growing shoots and the tubers connected to them by glyphosate. According to Adejonwo *et al.* (1991) use of pre-emergence herbicide mixture of metolanchlor plus prometryne at 2.0 and 1.0 kg a.i/ha, respectively, showed promising effectiveness on weed control as only one hoe-weeding was required. The study suggests that mulch and herbicide could be used to control weeds early in the growing cycle for good crop establishment while reducing weeding operations. According to Stall (1996) the plant that emerges first and grows most rapidly is the one that will have most competitive advantage during the crop growth cycle.

The study survey data from farmer fields revealed that 5 - 8 insecticide applications per season significantly reduced insect pest populations. Generally insect counts for whitefly colonies, thrips and bollworm larva did not exceed one throughout the study. An action threshold of approximately 45% of flowers with 5 or more adult western flower thrips was recommended (Steiner and Goodwin 2005). Consistently, grower standard and IPM treatments indicated low insect pest and beneficial insect populations at On-station field experiment throughout the season. However, IPM indicated higher insects count than grower standard. Reduced insects population in grower standard treatment could be due to the direct effects of insecticide through ingestion and contact, indirect effects such as insecticide repellence, and shortage of food for predator. Similarly Men *et al.* (2004) found insecticide applications against other insect pests decreased the densities of mites significantly and Vandekerkhove and de Clercq (2004) reported that nymph and adults of green stink bug (*Nezara viridula*) were highly susceptible to insecticide both by ingestion and contact exposure.

Natural enemy populations were severely reduced by insecticide applications and also dependent on insect numbers (Miranda *et al.*, 2005). According to Hoffmann and Frodsham (1993), chemical insecticides adversely affect natural enemies than targeted pest, this is because natural enemies had high chances of coming into contact with insecticides as they are very mobile and spend a considerable amount of time moving across plant tissue searching for their prey. Similarly, Vardim and Edward (1998) reported that killing of prey caused food shortage thus predators were starved.

However, steady leafminer incidence decrease in check treatment could be due to failure of insect to locate host as a result of high weeds population. This implies that, routine sprays of insecticide did not allow buildup of insects' population to an economic damage level. The study suggests that insecticide applications should not be done routinely to reduce cost of production and unnecessarily killing of beneficial insects.

Use of fertilizer, mulch and intercropping spider plant with tomato showed high insect pests and mite population on tomato crop. High aphid and leaf miner incidences, thrips, thrips per 5 flowers number per plant were observed in fertilizer and mulch treatments, possibly could be due to improved plant growth and development which offered excellent source of food and favourable environment to the insects. Furthermore, higher mite population in fertilized than unfertilized treatments was probably influenced by nutritional status of the plant tissue. Phelan *et al.* (1995) reported that N fertilization increased soluble N levels in plant tissue which generally decreased pest resistance and Altieri and Nicholls (2003) noted that increase in nitrogen rates dramatically increased mite and aphid populations.

High number of whitefly colonies observed in mulch treatment compared to unmulched treatments could be attributed to bushy growth of plant which provided acceptable food source, large surface for oviposition and nymph development and camouflage against natural enemies. This is consistent with findings by Frank and Lihurd (2005) whereby higher whitefly adults and nymph populations in lower plant strata were found when studying the effect of reflective mulch on whitefly population dynamics. Higher bollworm larva infestation in tomato-spider plant intercrop could be attributed to bushy environment created by the two crops and/or prevailing weather conditions. Similar findings were observed by Rwezaura *et al.* (2005), whereby high bollworm infestations were observed on determinate tomato varieties compared to the indeterminate ones. AVRDC (1990) reported that large leaf surface area exhibited by bushy host plants provide habitat and oviposition site to bollworms hence higher infestation.

In the study to verify the effect of tomato-spider plant intercrop on tomato insect pests, the results showed significant high thrip populations on leaf and in flowers of tomato while nearly none was observed in spider plants. On the other hand, high aphid and leaf miner incidences and populations of predaceous insects such as spider and stinkbugs were observed in spider plant monocrop and intercrop treatments. High thrip populations on tomato plants than in spider plants in spider plant-tomato intercrop could be attributed to host preference or on the tomato plants. Similarly Brodbeck *et al.* (2001) reported that utilization of plant hosts unsuitable to predator by thrips is one of mechanisms for avoiding predation and tomato plant was cited as an excellent example. This suggests that intercropping as a strategy for insect pest control is not by itself effective; other pest control measures are required.

On the other hand, high aphid and leaf miner incidences in spider plant monocrop and intercrop treatments could be due to suitability of spider plant to some insect pests and by chance insects' migration to the adjacent tomato crop, respectively. However, high spider and bug populations on spider plants could be due to habitat diversification which created favourable habitat in terms of food and habitat for both beneficial insects and prey. Frank and Liburd (2005) reported similar observations, supporting the natural enemy hypothesis proposed by Root (1973) that increased plant diversity leads to increased natural enemy densities. Finding supports Jones and Gillett (2005) who reported that sunflower intercrop strips attracted and played host to numerous beneficial insects and insect pests suggesting that crop planted within rows of vegetable crops may indeed be an effective way to attract beneficial insects into cropped field. According to study observations, planting spider plants nearby tomato field can attract both beneficial insects and insect pests which could migrate to the main crop too if the attractive crop is very close. Therefore, the study suggests that instead of intercropping spider plants with tomato, spider plants could be used as a trap crop in tomato production. However, this association needs careful scrutiny as the plants host a wide range of similar insect pests.

This study suggests that spider plants should not be intercropped within tomato field due to their faster and robust growth; however, this will depend on the area and sharp of the field. Findings by Jones and Gillett (2005) showed that crop vegetation within one meter of strip plants harbored nearly the same abundance and diversity of beneficial insects as strip plants themselves and crop vegetation 10 m distance from strip plants had significantly fewer beneficial insects than within one meter. Like Jones and Gillett (2005) suggestion, a specified distance at which key beneficial insects and insect pests move from spider plants strip to the crop vegetation is required.

The study showed low late blight and leaf spot severity in IPM and grower standard treatments. This could be attributed to fungicide applications. Similarly, Fontem (2001) reported that late blight severity on potato was decreased with increased number of fungicide applications. Low late blight and leaf spot severity in mulching was attributing to reduced irrigation water splash as well as soil-leaves contact. Similarly Lyimo *et al.* (1987) reported that mulching reduced amount of initial inoculum reaching the plant which in turn reduced blight disease levels. This implies that incorporation of mulch in IPM may reduce the spread of disease pathogens and therefore reduce fungicide applications.

5.4 Growth and yield of tomato

Yield assessment at Mlali and Kipera showed that highest tomato yield obtained at Mlali farmer field (M2) was 66% higher than highest tomato yield obtained at Kipera field (K4). This could be due to fertilizer applications and that sufficient moisture availability in the field which facilitated the uptake of plant nutrients in the soil which improved plant growth and development. High disease damaged fruits category observed in the villages fields due to fruit rot could be attributed to fruit lying on ground predisposing fruit to pathogens.

At the on-station experiment conducted from mid November to mid February 2007 indicated that mulch treatment resulted into higher yield components (branch per plant, fruits per cluster, fruit weight and total fruit number and weight) compared to other treatments. The reduced yield components in other treatment could be due to higher temperature 28.6^{0}C experienced during the growing season. Such condition may have influenced the crop growth and nutrients uptake from the soil. Literature indicates that optimal temperature for tomato production is about 25^{0}C and affects crop performance as it rises above 25^{0}C (Oliveira and Calado, 1996). Similarly, Hudu *et al.* (2002); Sunilkumar and Jaikumaran (2002) reported increased plant height, number of flowers/plant, fruit sets/plant, number of fruits/plant and harvested total marketable fruit yield/ha in the mulched than the unmulched treatment. High number of fruits per cluster and fruit weight in mulched plots was due to fewer numbers of clusters per plant because much of assimilates were used for vegetative growth. Thus, fewer numbers of clusters per plant allowed reduced sinks for assimilates partitioning for fruit formation and growth. Furthermore, greater number of fruits per cluster was attributed to reduced flower abortion as a result of maintained moisture supply conserved by the mulch.

Mulch treatment yielded eleven times more tomatoes compared to check treatment. This yield reduction in control treatment was attributed to competition for plant growth resources by weeds. This is in line with findings of Kere *et al.* (2003). Also findings by

Rweyemamu *et al.* (1998) reported increase in tomato yields when rice husk and grass mulch were used.

Among physiologically damaged fruits, high number of sunny scotched fruits observed in mulch treatment was attributed to high temperature conditions, immediately reflected high solar energy and heat retained by mulch caused heating of the fruits lying on the ground. Similarly Rwezaura *et al.* (2005) reported high number of sun scotched fruits in rice husk and grass mulch. This suggests that to minimize detrimental effects of heat on determinate varieties support provision is important to take off fruits from the ground. High sunny scotch effect on fruits in one farmer field at Mwanga-Kipera was attributed to insufficient water supply. To overcome a problem, Kee *et al.* (2007) recommended sufficient moisture supply to improve plant growth.

The study showed large number of fruits with cracks in all treatments except in check and tomato/spider plants intercrop. This physiological damage was due to the prevailed high an uneven distributed rains and temperatures which caused moisture fluctuations resulting to rapid liquid increase in the fruits hence cracking. The study suggests that period of low soil moisture followed by frequent rainfall increases cracking. Similar opinion was given by Rweyemamu *et al.* (1998) who reported that damage of fruits by growth crack and splitting due to heavy rains did not improve crop quality. This implies that fruits should be harvested at early stage of ripening when rains are prevailing.

The observed high number of damaged fruits by bollworm in mulched, tomato-cabbage intercrop, fertilizer, and tomato-spider intercrop was attributed to bollworm feeding preference and bushy growth of the plant. Similarly Rwezaura *et al.* (2005), Rweyemamu *et al.* (1998) reported high fruits damage by fruit worms in determinate variety compared to indeterminate variety and Rwezaura *et al.* (2005) related this to growth types of the two varieties. Low fruit damage by bollworm in grower standard and IPM was due to insecticide applications. Miranda *et al.* (2005) reported that fruit production period, being the most critical phase of the crop, requires similar insecticide applications in IPM as calendar insecticide spraying system to control fruit worm infestations. This emphasizes the importance of applying low cost, effective and safer insecticides for controlling the insect to enhance market value.

Results of the study showed high fruit damage in fertilizer, mulch, IPM, tomato-cabbage and tomato-spider plant intercrops by early and late blight probably was due to high temperatures and relative humidity during the growing season which favoured pathogen development. Similarly Rweyemamu *et al.* (1998) reported poor fruit quality due to late blight following rainfall despite of mulch use. The study also showed significant higher number of fruit rot in mulch compared to check, this could be due to large number of fruits produced and high moisture retained on mulch materials which favoured survival of pathogen and/or contact of the fruits with the soils predisposed to the soil borne pathogens.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

On the basis of the results of this study, the following conclusions could be drawn:

i. Nutsedges (*Cyperus* spp), leafminer and Septoria leaf spot are the major important weed, insect pest and disease of tomato, respectively, at Mlali and Kipera village.

ii. There were intensive use of fungicides and insecticides on tomato production by tomato growers which reduced disease occurrences, insect pests population and beneficial insects population.

iii. Mulch was effective in suppressing germination and growth weeds by creating unfavourable conditions and application of glyphosate in IPM was effective in suppressing population of weeds by killing the actively growing weeds. The combination of these practices could prolong the period of weed free in the fields. This will not only suppress increase in weeds population but time and labor costs will be saved by reducing number of hoe-weedings. Furthermore, insect pests and diseases will be controlled effectively.

6.2 Recommendations

i. Farmers should be trained in different management techniques of pests so as to have a wide range of choice among alternatives. Farmers should be encouraged to use chemicals as a last resort.

ii. In order to improve tomato production in terms of quantity and quality while reducing high use of agrochemicals, farmers should be encouraged on mulching and IPM.

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APPENDICES

Appendix I: Farmers' name and field location

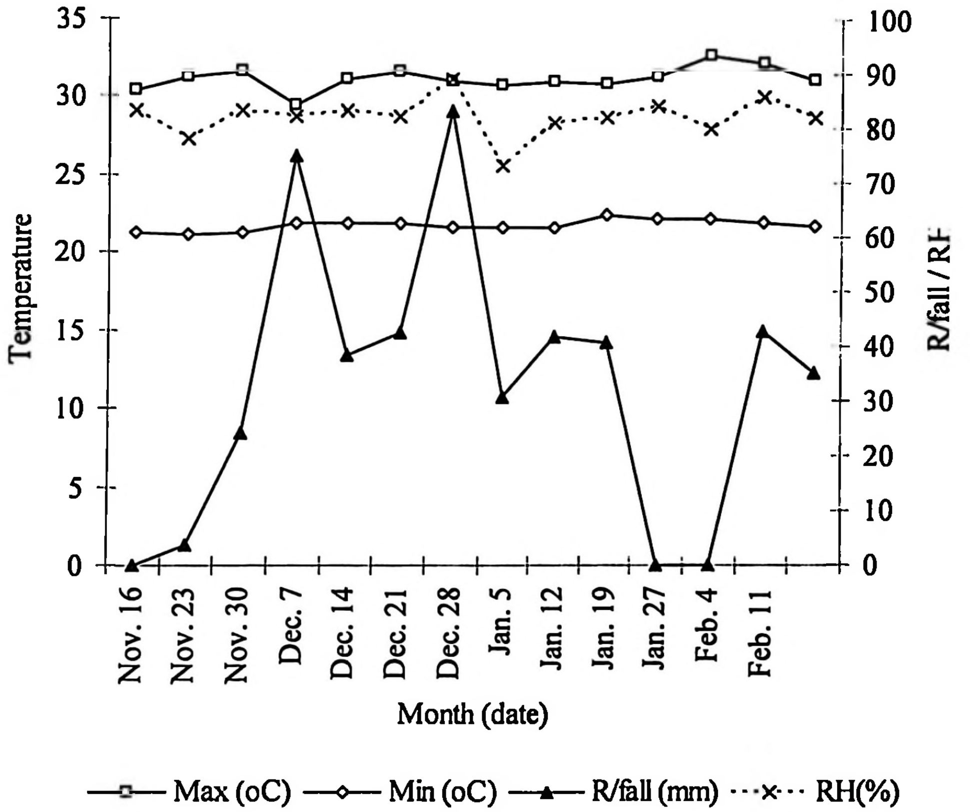
Farmers' Field	Farmers' name	Site	Location		
			Altitude (m)	Latitude (S)	Longitude (E)
K1	Hamad	Ng'ole	544	$06^{0}56$	$37^{0}32'$
K2	Bernad	Ng'ole	543	$06^{0}56'$	$37^{0}32'$
K3	Shukuru	Mwanga	537	$06^{0}55'$	$37^{0}32'$
K4	Tauras	Mwanga	539	$06^{0}55'$	$37^{0}32'$
K5	Yahaya	Mwanga	540	$06^{0}55'$	$37^{0}32'$
M1	Calyst	Scheme	554	$06^{0}56'$	$37^{0}31'$
M2	Halfa	Scheme	555	$06^{0}56'$	$37^{0}31'$
M3	Nduguru	Scheme	555	$06^{0}56'$	$37^{0}31'$
M4	Kobelo	Scheme	554	$06^{0}56'$	$37^{0}31'$
M5	Mashaka	Scheme	554	$06^{0}56'$	$37^{0}31'$

K1 – K5 = Kipera farmers' fields, M1- M5 = Mlali farmers' fields

Appendix II: Disease rating

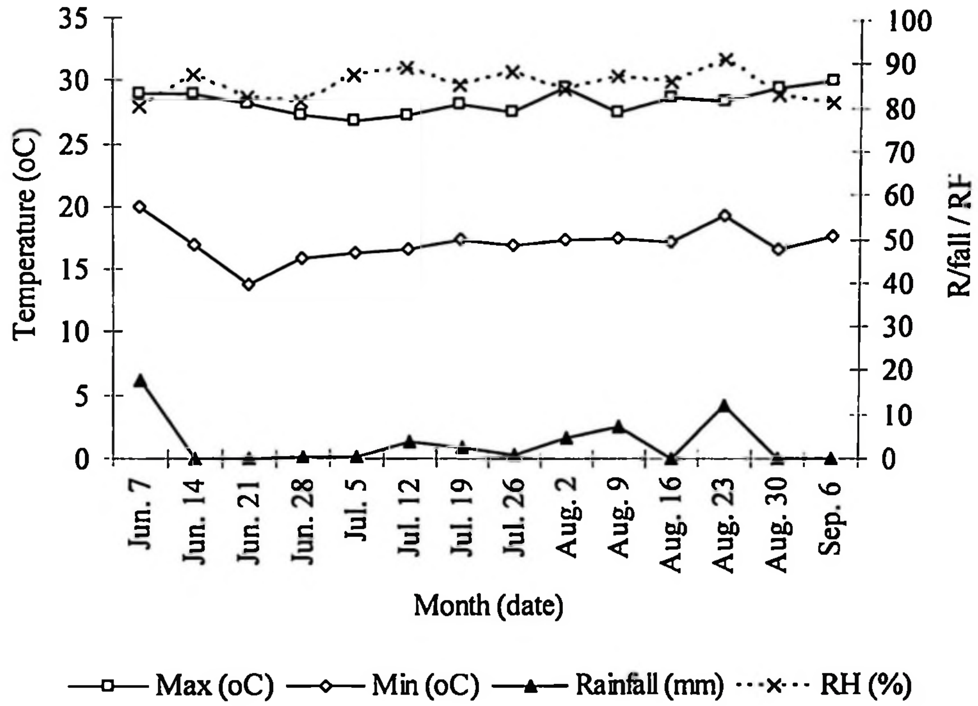
Disease score	% leaf damage	Severity
1	0	No disease
2	≤ 10	Low
3	$= 10 - 50$	Medium
4	≥ 50	High

Appendix IIIa: Weekly distribution of temperature, rainfall and relative humidity (RH) during the on station experiment (November – February 2006/07) in Morogoro



Aver. Max. temperature = 31.2 °C, Min. temperature = 21.8 °C, Rainfall = 35.2 mm, RH = 82%

Appendix IIIb: Weekly distribution of temperature, rainfall and relative humidity (RH) during the on station experiment (June – September 2007) in Morogoro



Aver. Max = 28.6 °C, Min = 17.2 °C, Rainfall = 3.3 mm, RH = 84.5%

Appendix IV: Soil physical and chemical characteristics taken at 0 – 15 cm depth before transplanting (2006)

Soil property	Results	Remark
Textural class		Sandy loam
Sand	68.1%	High
Silt	13.0%	Low
Clay	18.9%	Low
Organic carbon (%)	2.17	Medium
pH: H_2O	7.44	High
Total nitrogen (%)	0.11	Low
Phosphorus	62.27 mg/kg	
Potassium	0.43 cmol/kg	
Calcium	6.00 cmol/kg	

Appendix V: Fruit size grading

Grade size	Diameter (cm)	Remark
I	4	Very small
II	4.5	Small
III	5.5	Medium
IV	6.5	Large
V	8.0	Very large

Appendix VI: Insecticides and fungicides

Common name	Trade name	Chemical name	Concentration (a.i kg/ha)
Thionex	THIONEX 35 EC	Endosulfan	0.53 – 0.7
Selecron	SELECRON®720 EC	Profenofos	0.72
Karate	KARATE™5 EC	Lambda- Cyhalothrin	
Dithane	DITHANE-M 45	Mancozeb 80%	1.2 - 2
Atracobluc			
Farmerzeb	FARMERZEB 80 WP	Mancozeb 80%	
bluecopper	Cobox® 50 WP	Copper oxychloride 84%	3.36 – 5.04
Ridomil.	Ridomil® MZ 68 WP	Metalaxyl-M +Mancozeb	1.63
Ivory	Ivory M 72 WP	Metalaxyl-M +Mancozeb	2.20

Appendix VII: Percentage distribution of cumulative yield categories

Treatment	Cumulative yield category (%)			
	CM	PD	ID	DD
FTL	25	25	44	6
MLH	25	30	39	6
IPM	33	30	28	9
TCI	19	26	47	8
GRS	37	32	25	6
CHK	12	19	64	5
TSI	25	21	48	6

CM = Clean marketable, PD = physiologically damaged, ID = Insect damaged, DD = Disease damaged