# Survey of Production Practices and Evaluation of Onion Varieties Susceptibility to Thrips in Kirinyaga District, Kenya

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A thesis submitted in partial fulfillment for the Degree of Master of Science in Zoology (Agricultural Entomology) in the Jomo Kenyatta university of Agriculture and Technology

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## DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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## DEDICATION

This thesis is dedicated to my late mother, Naomi Njoki, who inculcated in me the need for patience and hard work at an early age in life but did not live long enough to witness the fruits of her efforts.

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## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| **AVRDC** | Asian Vegetable Research Development Center |
| **DAT** | Days after transplanting |
| **EurepGAP** | Euro Retailer Produce Working Group on Good Agricultural Practices |
| **FAO** | Food and Agriculture Organization of United Nations |
| **FAOSTAT** | Food and Agriculture Organization of United Nations Statistics |
| **GAP** | Good Agricultural Practices |
| **GoK** | Government of Kenya |
| **HCDA** | Horticultural Crops Development Authority |
| **IIE** | International Institute of Entomology |
| **IPM** | Integrated Pest Management |
| **JKUAT** | Jomo Kenyatta University of Agriculture and Technology |
| **KNBS** | Kenya National Bureau of Statistics |
| **KARI** | Kenya Agricultural Research Institute |
| **KIFCO** | Kibirigwi Farmers Co-operative Society |
| **NARL** | National Agricultural Research Laboratories |
| **NHRC-Thika** | National Horticultural Research Centre-Thika |
| **ODA** | Overseas Development Agency |
| **SAS** | Statistical Analysis System |
| **S.E** | Standard Error |
| **USAID-Kenya** | United States Aid for International Development-Kenya |

**ABSTRACT**

In Kenya, dry onion, *Allium cepa* L., is among the most important vegetable crops for domestic market. However, records indicate that onion production does not meet the local market demand resulting to imports. To identify onion production constraints experienced by onion growing farmers, a field survey was conducted in Kirinyaga District of Central Kenya, an area where commercial production of onions was promoted since 1950s. Insect pests were significantly rated as the most limiting factor in production of onions followed by diseases, lack of capital, unreliable onion market, weed control and inadequate supply of water for irrigation in that order. The findings of the present study were expected to provide baseline information upon which solutions to the many problems affecting onion production would be addressed.

The second part of this study involved evaluation of the level of susceptibility of onion varieties to attack by onion thrips (*Thrips tabaci* Lind.). Field trials were conducted at the Kenya Agricultural Research Institute (KARI) centres at Mwea and Thika. Results indicated that different onion varieties available in Kenya had different levels of susceptibility to attack by onion thrips. BSS 230 Hybrid and Red Comet onion varieties significantly harboured the highest and the lowest number of onion thrips respectively. Red Creole, Bombay Red and Texas Grano had medium levels of susceptibility. Highly leafy onion varieties tended to harbour a higher number of thrips compared to the less leafy ones. Infestations of onion varieties by large number of onion thrips adversely affected the growth of onion crop. Red

Comet although significantly harbouring the least number of onion thrips displayed the highest loss of growth and was, therefore, the least tolerant to damage by thrips. Onion varieties grown in Kenya had the capacities of producing over 30 t/ha. Texas Grano onion variety significantly produced higher yield than all other varieties tested. BSS 230 Hybrid was also high yielding despite the high number of thrips harboured by the variety. Red Creole and Bombay Red had moderate yield capacities. Red Comet significantly produced the lowest yield. Increased thrip load led to increased yield loss for all the varieties. However, Red Comet onion variety recorded the lowest thrip load but had the highest percent yield loss implying that it was least tolerant to damage by onion thrips. Infestations of various onion varieties by thrips were found to peak three months after transplanting. High temperatures and low rainfall tended to encourage higher levels of onion thrips on onion plants. It was revealed that the damage of onion leaves by onion thrips depended on their numbers. BSS 230 Hybrid and Bombay Red onion varieties were found to significantly show the highest foliar damage score compared to the rest of the varieties. There were no significant differences in the mean frequencies of onion foliar disease incidences among the varieties. However, infestations by onion thrips had the potential of increasing incidences of onion foliar diseases. Results indicated that Texas Grano and Red Comet onion varieties significantly produced the highest and the lowest quality onion bulbs respectively. Arising from the above findings, it could be recommended that regular outreach programmes should be conducted in the onion growing area by relevant stakeholders to address the identified production constraints. The present study should closely be followed by another survey to evaluate the impacts of the implementation of intervention strategies. On the other hand, Texas Grano could be recommended as an important variety to be grown in Kenya for markets where pungency was not an important quality factor. BSS 230 Hybrid, Red Creole and Bombay Red could also be recommended to farmers in Kenya. BSS 230 Hybrid and Red Comet required improvements through plant breeding programmes.

# CHAPTER 1

## 1.0 INTRODUCTION AND LITERATURE REVIEW

### 1.1 GENERAL INTRODUCTION

Onion, *Allium cepa* L. is a monocotyledonous plant belonging to the family Alliaceae (Malik, 1994). Onions are the oldest vegetables in continuous cultivation dating back to at least 4000 B.C. (Boyhan *et al*., 2002). There are no known ancestors, but the centre of origin is believed to be Afghanistan and the surrounding region. Onions are among the most adapted vegetable crops as they can be grown from the tropics to sub-arctic regions. The adaptation is primarily due to differing response to day lengths. Onions are, therefore, grouped into short-day or long-day varieties (Boyhan *et al*., 2002).

Nutritionally, onions are low in calories yet add abundant flavor to a variety of foods. Onions have low levels of sodium, fat and cholesterol and provide dietary fiber, vitamin C, vitamin B6, potassium and other key nutrients (Onion World, 2003). In addition, onions contain some phtochemicals that are beneficial to human health (Desjardins, 2008). These health benefits include reduction of factors that cause cardiovascular diseases, cancers, diabetes, inflammatory diseases among others (Cramer, 2002; Srinivasan, 2005).

Worldwide, bulb onion is the third most important vegetable crop after tomato and watermelon (FAOSTAT, 2006). The world leading onion producing countries in order of importance are China, India, U.S., Turkey, Russia, Japan, Iran, Netherlands, Mexico and Spain. The main onion producing countries in Africa include Egypt, Morocco, Niger, Kenya, Tanzania and Ghana in that order. The world leading onion exporting countries in order of importance are India, Netherlands, China, Egypt and U.S. Among the main onion exporting countries in Africa are Egypt, Tanzania, Morocco and Niger (Donna and Megan, 2007).

In Kenya, dry onion is the third most important vegetable crop for the domestic market, after brassicas and tomato. It is also an important source of income for small holder farmers and business community involved in the local and cross border trade (Kimani *et al*., 1990). They are grown in a wide range of agro-ecological zones, ranging from sea level to the upper highland areas below 2,000 m above sea level (USAID-Kenya, 2007). The main growing areas include Central, Rift valley, Western and Eastern Provinces of Kenya (Kimani *et al*., 1990). Although favourable conditions for onion production exist in Kenya, reports indicate that yields are generally low, ranging between 5 and 20 tonnes per hectare compared to over 30 tons per hectare in countries such as China, Spain and Japan (Kimani and Mbatia, 1993; Nguthi *et al*., 1994; FAO, 1999). The low yield and poor quality supply of bulb onions from Kenya is attributed to lack of appropriate pest management techniques, losses due to poor post-harvest handling and lack of marketing strategies (Tschirley *et al*., 2004).

The primary pests of onions include onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) and maggots of the onion fly, *Delia antiqua* Meigen

(Diptera: Anthomyiidae). *Thrips tabaci* is a cosmopolitan species found in all parts of the world where onions are grown (Lewis, 1973; Brewster, 1994; Macintyre-Allen *et al*., 2006). On the other hand, *D. antiqua* is mostly confined to temperate countries and its attack on onions is usually sporadic (Jones and Mann, 1963; Srinivasan *et al*., 1981; Sinha *et al*., 1984). In Canada, onion thrips is second to onion fly, *Delia antiqua* Meigen in economic importance in onions, causing losses of 43% (Fournier *et al*., 1995). Minor pests of onions include plant bugs, *Nysius natalensis* Evans (Hemiptera: Lygaeidae), the spider mite *Tetranychus urticae* Koch (Prostigmata: Tetranychidae), the white mite, *Petrobia luteus* (Muller) (Tetranychidae) and bulb mites, *Rhizoglyphus echinopus* (Fumouze and Robin) (Jones and Mann, 1963; Smith Meyer, 1974). Soil-borne onion pests include seed-corn maggots, *Hylemya cilicrura* Rondani, cutworms (Noctuidae), wireworms (Elateridae), stubby root nematodes, *Paratrichodorus minor* (Colbran), root-knot nematodes, *Meloidogyne arenaria* (Neal) and *M. incognita* (Kofoid and White) (Jones ans Mann,1963; Keetch and Buckley, 1984, Daiber, 1995). The other pests include western flower thrips, *Frankliniella occidentalis* Pergande, salt-marsh caterpillar, *Estigmene acrea* Drury, American bollworm, *Helicoverpa armigera* Hb, the golden wing moth, Plus*ia arichalcea* F. and pea leaf miner, *Liriomyza langei* Frick (Jones and Mann, 1963; Daiber, 1995; Waiganjo, 2004).

Studies conducted to identify thrips species associated with onion crops in Kenya indicated that *T. tabaci* was the dominant species accounting for 90% of all samples collected. Other species reported and their respective composition included western flower thrips, *Frankliniella occidentalis* Pergande (6.3%), bean flower thrips, *Megalurothrips sjostedti* Trybom (1.5%) cotton bud thrips, *Frankliniella schultzei* Trybom (1.4%), the gladiolus thrips, *Thrips simplex* Morison (0.3%) and a predatory thrips, *Aeolothrips sp*. (0.3%). *Frankliniella occidentalis* was reported to be more common in Kirinyaga District (accounting for about 44% of samples collected) compared to other onion growing areas in Kenya (Waiganjo, 2004). Apart from *T. tabaci* and *F. occidentalis,* the other species of thrips were probably on transit from other hosts and their pest status on onions remained uncertain (Waiganjo, 2004).

Pests have been reported as the most important production impediments often causing substantial yield losses in all the onion growing areas in Kenya (Waiganjo, 2004). Presently, the widely adopted onion thrips management strategy is routine pesticide spray. Studies have shown that sometimes the population of thrips may continue to increase despite frequent applications of toxic insecticides (Nagai, 1990; Funderburk *et al*., 2000). Attempts to control thrips populations by regular applications of insecticides have led to the development of insecticide resistance (Immaraju, *et al*., 1992; Morse and Hoddle, 2006).

The problem of insecticide residues has gained more prominence in the horticultural industry since the introduction of new regulations by the European Union for maximum residual levels (MRLs) in January 1994. Food safety standards in Europe with emphasis on traceability and process standards have become much stricter since January 2005 under EurepGAP, implying higher barriers to smallholder participation in export market. At the same time, people have become more knowledgeable on the dangers posed by insecticides to their health, their animals and the environment in general. In view of the high losses of marketable produce, an Integrated Pest Management (IPM) system is required.

An effective pest management strategy would incorporate host plant resistance amongst other options. Past efforts in identifying and utilizing host plant resistance to onion thrips in Kenya are apparently very limited. The important aspect of priority research is identification of onion varieties which are associated with antibiosis, antixenosis or tolerance to onion thrips infestations and have moderate to good yield potential. Such cultivars would reduce the pesticide burden on the crop, would not require additional inputs by the farmer and would, therefore, be economical in terms of pesticide requirements. One of the objectives of the present study was to identify onion varieties in Kenya which are less susceptible to attack by onion thrips and have moderate to high yield capacities.

## 1.2 LITERATURE REVIEW

### 1.2.1 Thrips as Pest of Crops

Thrips are minute to small insects measuring about 0.5 mm to 15 mm long (Palmer, 1990). They belong to the order Thysanoptera. They occur worldwide with many species occupying both in the tropical and temperate regions (Lewis, 1997). There are about 5000 described species placed into two sub-orders. These include Terebrantia and Tubulifera (Lewis, 1997). Terebrantia has several families including Thripidae. Tubulifera has only one family, the Phlaeothripidae (Loomans *et al.,* 1995). Thrips are considered as unique in having asymmetrical piercing and sucking mouthparts. Only the left mandible is present. They also have characteristic tarsi with an eversible, adhesive pretarsal bladder (Palmer, 1990, Lewis, 1997). The body is slender and elongate while the head is also elongate and usually hypognathous. Wings, when present, are narrow with reduced venation and marginal fringes of cilia, which give rise to the name of the order (*thysanos*, a fringe; *pteron*, wing) (Palmer, 1990).

The features of thrips biology that predispose them to be important crop pests are; their ability to multiply rapidly in favourable environments, their ability to cause direct feeding damage, or for a few species their ability to transmit viral diseases, and their tendency to spread and colonize widely, mainly by natural flight but also being transported within vegetation using planes, ships and vehicles (Lewis, 1997). Due to the need to raise food production and trade, endemic thrip species have transferred to new hosts and alien species have been introduced to new areas (Mound, 1983).

The life cycle of thrips involves an egg, two actively feeding larval stages, followed by two or three non-feeding stages (propupa and one or two pupal stages. The resulting adults may be fully winged, have short wings, or be wingless, depending on both the sex and the species (Mound and Kibby, 1998). In most terebrantia, eggs are inserted into plant tissue by use of a serrated ovipositor, although in a few species the ovipositor is weak and eggs are deposited on the plant surface. All species of Terebrantia have one pupal stage following the propupa, and pupation usually takes place in the soil away from the larval feeding site. The complete life cycle usually lasts between 10 to 30 days depending on temperature, with adults surviving for a similar period (Lewis, 1997). In warm regions and in greenhouses there may be up to 12 or 15 generations per year but in cooler regions there may be one or two generations per year. Overwintering is achieved as larva in a soil cell, or as adult among dead plant litter, crop debris or under tree bark (Lewis, 1973).

The males of thrips species have half the number of chromosomes (haploid number) that are found in females (diploid number) and are derived from unfertilized eggs (Palmer *et al.,* 1989; Mound and Kibby, 1998). Despite this haplodiploidy, many species have evolved the ability to reproduce in the absence of males (Crespi, 1993). Sexual dimorphism is usually common and is sometimes remarkable (Ananthakrishnan, 1969). Males of Terebrantia are usually smaller than females but males of fungus feeding Phlaeothripidae are often much larger than females (Palmer *et al.*, 1989).

Dispersal of thrips through the air is not dependent on the presence of wings. A number of wingless species have more effective aerial dispersal than some fully winged species. Many species of thrips have the habit of crawling to the top of a plant or twig and jumping (Palmer *et al.,* 1989; Mound and Kibby, 1998). Although weak flyers, the fringed wings of some species of thrips enable them to remain airborne long enough to travel easily between neighbouring fields and frequently over far greater distances (Lewis, 1997).

Thrips are among the stealthiest of insect invaders due to their small size and cryptic habits. Many invasive thrips are notorious for causing extensive damage, vectoring viral diseases and permanently destabilizing IPM systems owing to outbreaks that require remediation with insecticides and ultimately leading to the development of insecticide resistance (Morse and Hoddle, 2006).

Most species of thrips possess population characteristics that include polyphagy, agility, a short generation time, a moderately broad food tolerance, tendency towards parthenogenesis and possibly a competitive breeding structure that promote aggregation (Mound, 1997). These population characteristics are advantageous in exploiting the transient optimal conditions of a growing crop, and pose problems when attempting to manage populations with conventional pest management methods such as chemical insecticides (Mound, 1997).

Thrips are commonly thought of as flower-dwellers, but many species live on leaves, a few are predatory and probably about 50% of the species feed on fungi (Palmer *et al*., 1989). Most crop damaging thysanopterans belong to the family Thripidae (Loomans *et al.,* 1995). Many crops are susceptible to attack by thrips. These include onions, leeks, garlic, cocoa, tea, coffee, citrus, pyrethrum, beans, cowpeas, pigeon peas, cotton, tomato, brassicas, tobacco, pineapple, groundnuts, bananas, maize and other cereal crops. Many plants both wild and cultivated act as alternative hosts e.g. alfalfa, milkweed and other weeds (Palmer, 1990). Many thrips species are polyphagous and it is often these which cause particular problems to agriculturalists. Population can build up on vegetation including weeds surrounding a crop which is then infested by immigrants when the crop reaches a suitable stage of development (Ananthakrishnan, 1984).

The overall effect of infestation of a crop depends on many factors viz: the size of thrips population, the plant growth stage, its susceptibility to oviposition damage, direct feeding or to viral infection, the duration of infestation and suitability of weather for population growth (Lewis, 1997). Additional problems may be caused by a few thrips species known to transmit Tomato Spotted Wilt Virus and bud necrosis of groundnuts and those that are mechanical vectors of fungi and bacteria causing mildews, moulds and rusts (Ananthakrishnan, 1984; Lewis, 1997).

### 1.2.2 Economic Importance of Onion Thrips in Onion Production

*Thrips tabaci* is a cosmopolitan species found in all parts of the world where onions are grown (Lewis, 1973; Brewster, 1994; Macintyre-Allen *et al.*, 2006). They are considered a serious economic pest of onions, leeks, garlic and shallots worldwide (Boyce and Miller, 1954; Theunissen and Legutowska, 1991; Brewster, 1994). In Central Europe, *T. tabaci* is the most serious pest of onion and leek (Legutowska, 1997; Richter *et al.*, 1999). By far the most common and damaging insect found on New Mexico onions is thrips. Two species, western flower thrips, *Frankliniella occidentalis,* and onion thrips, *T. tabaci,* are the most common (Brad, 2002). In Western Colorado in US, onion thrips is the primary pest of onions (Sommers, 2007). Thrips are the main onion pest in Pakistan (Malik, 2005). In East Africa, *T. tabaci* was first recorded by Wilkinson in 1937 on pyrethrum in Kenya where it was causing damage to inflorescence (de Pury, 1968; KARI/ODA, 1994). Bullock (1957) reported its pest status in pyrethrum in Kenya. Later, onion thrips was recorded on onions, pyrethrum and leeks in Kenya and Tanzania (Le Pelley, 1959).

Onion thrips have a broad host range that includes broad-leaved plants and grasses. They are pests of agricultural crops, home gardens, landscapes and greenhouses. Primary vegetable and field crop hosts include onion, garlic, leek, cotton, cabbage, tobacco, pea, cucumber, melon, lettuce, asparagus, potato, cauliflower, small grains, bean, tomato, carnation, and chrysanthemum (Anyango, 1987; Loomans *et al*., 1995; Parella and Lewis, 1997; Alston and Drost, 2008). Thrips are present throughout the year, with adults surviving the winter on weeds, overwintering crops (including alfalfa and onions) and ornamental trees and shrubs (Brad, 2002). Population of onion thrips can also be maintained on surrounding weeds between successive plantings (Palmer, 1990). A search to identify alternative host flora of onion thrips in the onion ecosystem of Balochistan, Pakistan revealed that onion thrips inhabit many plants belonging to Cruciferae, Cucurbitacae, Gramineae, Leguminosae, Malvaceae, Moraceae, Papaveraceae, Rhamnaceae, Amaranthaceae, Asteraceae, Brassicaceae, Chenopodiacea, Solanaceae, Umbelliferae, Convolvulaceae, Cyperaceae, Euphorbiaceae, Liliaceae, Polygonaceae and Poaceae families (Malik, 2005).

Onion thrips are small in size and have strong thigmokinetic behavior. These characteristics enable thrips to hide in the protected narrow crevices of the inner leaves, near the onion bulb and under the leaf folds, making it difficult to detect them until feeding damage is apparent. The egg, larval and adult stages are found on the onion plant but pupation occurs in the soil (Anyango, 1987; Loomans *et al.*, 1995; Lewis, 1997). Adults insert their eggs into plant tissues. Upon egg hatch, there are two active, feeding larval stages that resemble the adult in general shape, but are smaller and lack wings. The larvae of onion thrips are pale yellow and feed at the base of onion leaves while the adults vary from light brown to dark brown. The larval stages are followed by two non-feeding stages referred to as prepupa and pupa (Cranshaw, 2004).

Thrips cause damage to onions by using their rasping-sucking mouthparts to abrade the plant epidermis and suck up the exuding plant sap. This causes characteristic scarring of the leaves and removes fluid and nutrients from leaf tissue. Localized tissue necrosis from feeding reduces photosynthetic ability and nutrient availability to the plant for setting and sizing the bulb, resulting in reduced yield (Coviello and McGiffen, 1995). In addition, there is evidence of greater ethylene production in onions damaged by thrips which enhance foliage scenescence (Kendall and Bjostad, 1990). Onions infested with *T. tabaci* develop silvery leaf spots that coalesce into white blotches due to removal of cellular contents and silvery patches develop along the inner angles of onion leaves, which eventually curl. Direct feeding damage to leaves by the ingestion of sap is most harmful in dry climates and seasons when heavily attacked plants lose moisture rapidly. In these conditions, infestation can seriously deplete yields (Lewis, 1997). On the other hand, many crops can outgrow damage to seedlings and young plants, and eventual loss are small or undetectable (Lewis, 1997). Research has shown that onion and leeks are capable of compensating for damage done by thrips (Richter *et al*., 1999).

Feeding injuries by thrips also predispose the plant tissues to subsequent invasion by bacterial and fungal pathogens (McKenzie *et al.,* 1993; Lewis, 1997). Onion plants attacked by onion thrips and inoculated with the fungal pathogen *Alternaria porri* Ellis develop more and larger lesions that tend to coalesce as the plant matures (Childers, 1997). Older leaves are more susceptible to this pathogen in the absence of thrips injury, but infection shifts to younger leaves when thrips feed on them. More tissue is killed by onion thrips in the presence of the fungus than in its absence and plant growth is negatively correlated with feeding injury (Childers, 1997). When both thrips and disease are present, the pathogen penetrates surfaces pierced by thrips and necrotic spots appear on leaves (McKenzie *et al*., 1993).

Studies on the role of *T. tabaci* on onion diseases have demonstrated an association between thrips populations and bacteria and fungi pathogens such as purple blotch caused *A. porri* Ellis (Ananthakrishnan, 1984; Thind and Jhooty, 1982; Bhangale and Joi, 1983; Bournier, 1983; Mayer *et al*., 1987; McKenzie *et al.,* 1993; Kaur *et al*., 1994) and leaf blight caused by *Botrytis squamosa* Walker (Kranthausen, 1989). Studies on tospovirus transmission have implicated *T. tabaci* to be a vector of onion tospovirus and iris yellow spot tospovirus in Brazil (Rescenda *et al.* 1996; Nagata, 1999), Israel (Gera *et al*, 1998) and India (Kumar and Rawal, 1999).

The most serious effect of thrips infestation is the resultant reduction in bulb yield (Kendall and Capinera, 1987; Coviello and McGiffen, 1995). Yield losses ranging between 18% and 60% with thrips population densities of 19.6- 62.0 thrips per plant have been reported in Kenya and infestation levels from 17.9 thrips per plant and below were found not to exert any significant difference in onion yield (Waiganjo, 2004). Records from many parts of the world indicate heavy losses because of T. *tabaci* infestation in onions. For example, both Raheja (1973) and Mali *et al.* (1985) recorded 50% yield losses due to onion thrips in Nigeria and India respectively. In Portugal, Boica *et al.* (1987) showed that onion thrips were responsible for yield loss of 62% while in Brazil, Domiciano *et al*. (1993) reported 40% yield loss due to onion thrips infestation. In Quebec (Canada), heavy infestation by onion thrips resulted in losses of 43% and 34.5% in 1988 and 1989 respectively (Fournier *et al.,* 1995).

Research by Sanderson (1995) demonstrated that thrips feeding had the potential to significantly reduce onion yields. The reduction was in form of smaller onion bulbs that resulted from the feeding activity after bulbing. Feeding damage during sizing usually results in early neck collapse (Brad, 2002). Yield reduction due to reduced bulb size is the primary crop loss caused by onion thrips. Accelerated plant maturity and senescence due to thrips injury may truncate the bulb growth period. Following harvest and during storage, thrips may continue to feed on onion bulbs, causing scars that reduce quality and aesthetic appearance of bulbs (Alston and Drost, 2008). Effective management of onion thrips is, thus, inevitable for economic production of onion crop.

### 1.2.3 Onion Thrips Control

The management of insect pests usually utilizes integrated strategies to maintain pests at acceptable levels. Integrated Pest Management (IPM) is an ecologically based pest control strategy that relies heavily on natural mortality factors and seeks out controls that disrupt these factors as little as possible. The aim of integrated pest management is not to eliminate all pests since some are tolerable and essential so that their natural enemies remain in the crop. Rather, the goal is to maintain pest populations below levels that can cause economic damage. Economic damage is the amount of injury which will justify the cost of artificial control measures (Stern *et al*, 1959).

Integrated pest management programmes are based on a number of principles. These include: the biology of the thrips and the damage caused, the spatial distribution of the pest within and between plants, the influence of host plant resistance on thrips biology, the importance of natural enemies in regulating thrips populations, the importance of cultural and physical control options and the utility of chemical control options (Parrella and Lewis, 1997).

#### 1.2.3.1 Population Dynamics of Onion Thrips on Onion Crop

The size of a population changes as a result of natality, mortality, immigration and emigration. If these processes and factors that influence them are well understood, population dynamics of an insect pest can be predicted. This would allow the design of effective IPM strategies and provide advance warning of outbreaks (Kirk, 1997).

The population dynamics is controlled by abiotic and biotic factors including trophic influence of the host plant (Sithanantham *et al.,* 2004). Biotic factors for consideration in explanatory models are host plant characteristics, predation, parasitism and disease. These factors affect thrips abundance (Lewis, 1959, 1973, 1997; Ananthakrishnan, 1993; Kirk, 1997).

Temperature affects the mortality and fecundity as quantified for *T. tabaci* by van Rijn *et al.* (1995). In combination with other abiotic factors it is assumed to largely control population development. Domiciano *et al.* (1993), while studying the association of population fluctuation of thrips on onion with climatic elements, reported that typical conditions favouring rapid increase in thrips population occurred with maximum temperature of 20-29°C, together with absence of rainfall. The authors reported that, thrips populations demonstrated a negative correlation with relative humidity and positive correlation with temperature. Similar findings were reported by Lorini and Junior (1990), who further reported that high temperature and lack of rainfall increased the population densities of thrips and recommended early planting since it permitted the crop to escape the pest population peak at its critical growth stage.

Rainfall, combined with cool temperatures, was shown to be detrimental to thrips in onions whereas, warmer and drier conditions led to increased densities (Harding, 1961). Heavy rain was reported to affect thrips population by washing thrips off plants and down to the soil surface, causing sudden sharp declines in their population density (Harris *et al.*, 1936). In a similar way, irrigation at the soil surface was reported to reduce the population more than rain probably as a result of soil caking killing thrips in the soil (Kirk, 1997).

Studies on onion thrips control by irrigation management at the Asian Vegetable Research and Development Centre (AVRDC) in Taiwan, demonstrated inverse relationship between level of irrigation and onion thrips damage rating. The authors observed that damage was higher under dry conditions and hence hypothesized that, high soil moisture enhanced entomopathogenic fungal growth, resulting in a greater degree of thrips pupal infection, which reduced the thrips population and subsequent crop damage (AVRDC, 1998).

The population dynamics of onion thrips and the many factors that influence their abundance in onion fields in Kenya is poorly understood. The effects of weather variables notably, rainfall and temperature on onion thrips population were investigated in the current study.

### 1.2.3.2 Pest Resistant Onion Varieties

The development and incorporation of resistant varieties into IPM for thrips control is still unexploited (Parrella and Lewis, 1997). However, in the near future, host plant resistance is likely to play an ever increasing role in pest management programmes (Smith, 1990). Painter (1951) defined plant resistance to insects as the 'amount of heritable qualities' possessed by the plant which influences the ultimate degree of damage by the insect. He divided insect resistance mechanisms into three categories: non-preference or antixenosis, antibiosis and tolerance. Antixenosis is the resistance mechanism employed by the plant to deter colonization by an insect. The deterrent may be biochemical and/or morphological factor that affect insects' orientation towards plants for food, oviposition sites or shelter. Antibiosis is the mechanism by which a colonized plant is resistant because it has an adverse effect on an insect's development, reproduction and survival. Plant tolerance is described as the extent to which a plant can support an insect infestation without loss of vigour and reduction of crop yield (Dent, 1991).

Onion thrips readily develop on all currently grown cultivars (Cranshaw, 2004). There is no known 'true tolerance' in onions to thrips. However, some onion varieties can tolerate effects of thrips feeding with only mild yield loss (Alston and Drost, 2008). Several studies have shown that some genotypes of bulb onions are resistant to *T. tabaci* (Coudriet *et al*., 1979, Brar *et al.*, 1993) depending on leaf structure and growth form (Terry, 1997). In India, Patil *et al.*, (1988) reported Hissar II and N-2-4-1 onion varieties, which had a wide angle of leaf emergence to be less susceptible to onion thrips. In Pakistan, Peshwar local, Quetta, Swart and Faisalabad onion varieties were reported to less susceptible to onion thrips infestation (Khan, 1997). Studies conducted in Egypt showed that onion cultivars Giza 6, Behiri, Granex 33 and Quetta were less prone to onion thrips attack (El-Gendi, 1998) while in Brazil, Boica et al., (1987) reported that Texas Grano, Baia do cedo and Granex onion cultivars were less infested by onion thrips. Research trials conducted at Colorado State University, USA, indicated that White Keeper onion variety was highly tolerant to thrips feeding injury while El Charro, Snow White, Vega, X 201 and Zapotec cultivars were moderately susceptible. Among the susceptible onion varieties according to the study included Blanco Duro, Brown Beauty, Brown Beauty 20, Colorado 6, Sweet Perfection, Tango, Valdez and White Delight. Early Red Stockton, Mambo, Red Baron and Redman onion cultivars were found to be highly susceptible to onion thrips infestation (Cranshaw, 2004). In another study in Czech Republic, the lowest levels of onion thrips infestation were found in waxless onion cultivars with light green leaves. These cultivars included De Grano/Banko, Yellow Sweet, Spanish, Sweet amber F1, and Foxy F1. The red cultivars were the most heavily infested by onion thrips (Bocak, 1995). Trials conducted in Punjab, India revealed that onion genotypes PBR 3, PBR 4, VL 1, No. 18, No. 19 and Pusa Ratnar were less preferred by *T. tabaci* (Brar *et al.*, 1993). Field trials conducted in Pakistan revealed that the Local Kandhari followed by Sariab Surkh onion varieties were the most susceptible to onion thrips infestation (Malik, 2005).

The mechanisms of onion cultivar resistance to onion thrips infestation have not been well studied. However, morphological and anatomical characters such as orientation of leaves and glossiness of foliage were reported to affect thrips populations (Sithanantham *et al*., 2004). Morphological characters, especially round or flat-sided leaves and open plant architecture, have been reported to be associated with low thrips densities on onion cultivars (Coudriet *et al.*, 1979). Lack of protection from pesticides, natural enemies, and adverse abiotic conditions were suggested as mechanisms of such resistance (Fournier *et al.*, 1995). Molennar, (1984) studied onion varieties with glossy and double gloss foliage and indicated non-preference as a mechanism accounting for the differences observed. Onion varieties with glossy foliage were found to be less prone to attack by onion thrips probably due to the chemistry of their leaf waxes. White onions were reported to be less susceptible to attack by onion thrips than red ones (Verma, 1966; Lall and Singh, 1968, Lewis, 1997). Greatest susceptibility to onion thrips injury was reported to be particularly common among red onions such as Mambo and Early Red Stock (Cranshaw, 2004). The low thrips infestation on white onion varieties was probably due to the foliage colour being less green and the spreading nature of leaves besides the early maturity of the varieties (Patil *et al.*, 1988).

#### 1.2.3.3 Biological control of Onion Thrips

Biological control is the use of any biological agent to reduce insect pest populations. Natural enemies of insect pests also referred to as biological control agents include predators, parasitoids and pathogens. Predators are free-living organisms that consume a large number of preys during their life time. Parasitoids are organisms whose immature stages develop on or within a single insect host, finally killing it. Pathogens are disease-causing organisms including bacteria, fungi and viruses (Hoffmann and Frodsham, 1993).

Natural enemies as control agents of onion thrips have not bee widely studied. However, records indicate that predators are the main natural enemies of *T. tabaci* (Sithanantham *et al.*, 2004). Recent review of predators attacking onion thrips indicate that most of the species belong to the families Anthocoridae, Miridae, Chrysopidae Aeolothripidae, Syrphidae, Sphecidae, Dolichoporidae, Coccinellidae, Malachidae, Staphilinidae, Gryllidae, Nabidae, Aganatidae and Phytoseiidae (Sabelis and van Rijn, 1997). Most of the predators of onion thrips have been successful in green house conditions but their impacts in field conditions have shown mixed results. The primary predators that feed on thrips in onion fields in Utah, USA include the black hunter thrips (*Aelothrips sp*.), big-eyed bug (*Geocoris spp*.), minute pirate bug (*Orius spp*.) and green lacewing, *Chrysoperla spp.* (Alston and Drost, 2008). A field experiment conducted in Germany to determine the possible use of predatory mites, *Amblyseius andersoni* and *A. limonicus* as biological control agents against *Thrips tabaci* revealed that both species were able to maintain the pest population below the level of pesticide treated area (control). However, even distribution of the release of the mites did not increase the efficiency compared to mass release on two dates (Drescher *et al.*, 2000). In another experiment in a controlled environment in Germany, *Orius niger* (Wolff) (Heteroptera: Anthocoridae) was found to be an effective predator for the immature stages and for the adults of *F. occidentalis* and *T. tabaci* (Deligeorgidis, 2002). Trials to evaluate the biological control of *T. tabaci* by *Amblyseius cucumeris* (Oudemans) (Acarina: Phytoseiidae) on greenhouse cucumber in Adana, Turkey indicated that the predator was able to bring thrips population down to low levels (Kazak *et al.*, 1999).

Most of the thrips parasitoids belong to order Hymenoptera in the superfamily Chalcidoidea. However, on worldwide basis only two genera, *Goetheana* and *Ceranisus* have been reported to parasitize on *T. tabaci* from various host plants. Examples of species attacking *T. tabaci* include *C. menes* (Walker), *C. russelli*, *C. americensis* (Girault) and *G. shakespearei*. The rates of parasitism by *C. menes* against *T. tabaci* reported from various parts of the world range from 0 to 25% (Sithanantham *et al.*, 2004).

Nematodes and entomopathogenic fungi have been reported as the two groups of pathogenic organisms which attack onion thrips. The two main species of nematodes which have been reported to parasitize on thrips include *Thripinema nicklewoodii* and *T. renirao* (Loomans *et al.*, 1997). However, there are no reported efforts to utilize nematodes for augmentation biocontrol of onion thrips (Loomans *et al.*, 1997).

Entomopathogenic fungi are the most commonly reported pathogens from thrips. Trials to evaluate the potential of *Verticillium lecanii*, *Beaveria bassiana*, *Paecilomyces fumosoroseus and Metarhizium anisopliae* as biocontrol agents against onion thrips and western flower thrips indicated that *T. tabaci* was more susceptible to all the entomogenous fungi tested than F. *occidentalis*. *Paecilomyces fumosoroseus, B. bassiana and* one isolate of *M. anisopliae* showed the highest virulence towards both thrips species (Gindin *et al.*, 1996). In Kenya, a field trial of the entomogenous fungus *Metarhizium anisopliae* for control of onion thrips, *Thrips tabaci* indicated that the fungus had the potential for controlling the pest while protecting biodiversity in the onion agroecosystem (Maniania *et al*., 2003).

#### 1.2.3.4 Cultural control of Onion Thrips

Cultural practices are a manipulation of the cropping environment to increase pest mortality or reduce rates of pest increase and damage ((Hoffman and Frodshem, 1993). There are many agricultural practices that make the environment less conducive to insect pests. Common cultural practices for thrips control include crop rotation, cultivations, irrigation, trap crops, time of planting and harvesting, mulching and intercropping (Parella and Lewis, 1997, Alston and Drost, 2008).

Records have shown that cultural practices adopted against *T. tabaci* have played a key role in suppressing thrips population in onions and other crops. Crop rotation is useful against soil-borne species or those on crop residues. In warm areas, *T. tabaci* may survive in plant remains left in fields, and new crop should not be planted on or near the sites of old ones (Parrella and Lewis, 1997). Soil- dwelling stages of thrips are vulnerable to mechanical cultivations (Parrellla and Lewis, 1997). Observing pre-planting and post-harvest sanitation where volunteer onion plants and debris are removed and destroyed may help to lower the number of onion thrips in the subsequent season. It was reported that onion transplants found to be infested by *T. tabaci* should be discarded (Alston and Drost, 2008). Overhead sprinkler irrigation has been shown to reduce thrips population on onion plant by washing the insects off the plants and also enhancing the formation of soil crust which reduce the ability of pre-pupae and pupae to seek shelter in the soil (Alston and Drost, 2008). Trap crops are planted to attract and hold pest insects where they can be managed more efficiently and prevent or reduce their movement onto valuable crops (Hoffmann and Frodsham, 1993). Trap crops which are highly attracted to *T. tabaci* include carrot, crucifers, cucurbits, carnation and chrysanthemum (Alston and Drost, 2008). Adjusting the timing of planting or harvest is another control tactic. Onion cultivars transplanted early were reported to escape from high onion thrips population densities and delayed transplanting enhanced pest infestation and yield losses (Gonclaves, 1996; 1997). Late transplanting of onions was shown to result in higher levels of infestation by *T. Tabaci* (Dawood and Haydar, 1996). Straw or other mulch materials have been reported to reduce thrips population and improve growth of onion crop. The benefits of mulch include weed suppression, soil and water conservation and enhanced soil organic matter. Effects of mulch on thrips may include increased biological control through enhanced predator populations, creation of a barrier for pre-pupae and pupae to access soil and reduced temperatures which slow thrips development and population increase (Alston and Drost, 2008). Silver mulches were reported to be effective in repelling onion thrips infesting shallot seedlings (Lu, 1990). Inter-cropping of onions and carrots has been shown to reduce onion thrips population on onions by attracting them to the carrots (Alston and Drost, 2008). In Egypt, intercropping onion and garlic with tomato reduced infestations of *T. tabaci* by about 80%, but the yield from both crops decreased (Afifi and Haydar, 1990). In England, infestation of *T. tabaci* on onions was reduced to 50% when intercropped with carrots (Uvah and Coaker, 1984). The effects were probably as a result of shading of the lower crop by the taller intercrop, which influences the abundance and activity of the thrips (Kyamanywa and Ampofo, 1988). Full field undersowing of leeks with clover, *Trifolium fragiferum* resulted in significant onion thrips population suppression and good yield. Reduced thrips feeding symptoms was also recorded in the intercropped leeks (Theunissen and Schelling, 1998). A mixed cropping system was shown to encourage a major thrips predator, *Orius tristicolor* (White), compared with monocultures (Letourneau and Altieri, 1983). The underlying causes of the predator accumulation were found to be independent of prey density and plant diversity but dependent on plant architecture and density (Letourneau, 1990).

#### 1.2.3.5 Chemical control of Onion Thrips

Insecticides are the most common strategy for onion thrips management (Alston and Drost, 2008). Several insecticides have been reported to significantly reduce onion thrips populations but their effects on yield have shown mixed results. In Slovenia, spinosad and abamectin were found to exhibit the highest efficiency against *T. tabaci* (Zezlina and Blazic, 2003). Trials conducted in Egypt to test the effects of some insecticides against *T. tabaci* indicated that carbofuran was the most effective, followed by profenofos, methomyl and pirimiphos-methyl, while mineral oil was the least effective in controlling the pest (Sailam and Hosseny, 2003). An experiment conducted to evaluate different insecticides (talstar, bifenthion, tamaron, methamidophos, bulldock, beta-cyfluthrin, talstar + tamaron) for the management of onion thrips in the agroclimatic conditions of Pakistan indicated that all the insecticides were equally effective in controlling the pest between one and seven days after application and all resulted in higher onion yields compared to the control (Khan *et al*., 2001). Field trials carried out in Gujarat, India revealed that emulfifiable concentrate (EC) insecticide formulations were more efficacious and economic to use compared to granular formulations (Butani and Kapadia, 1999). Studies using insecticides methyl parathion, carbofuran, trichlorfon, chlorfenvinphos, endosulfan, dimethoate, beta-cypermethrin, methamidophos, chlorpyrifos and tetradifon indicated that all the insecticides suppressed thrips populations at varying degrees and slightly increased seed and bulb yield compared to untreated plots (Gul *et al*., 1999). Control of *T. tabaci* in leeks by seed-coating using fipronil and imidacloprid gave good results but carbofuran, diflubenzuron, methiocarb, teflubenzuron and vamidothion were less effective. The most effective insecticide, fipronil did not cause phytotoxicity whereas imidacloprid reduced and slowed germination (Ester *et al.,* 1997). Of several insecticides tested against *T. tabaci* on onion in Egypt, fenvalerate, dimethoate and methomyl gave 100% mortality one day after application but fenvalerate and dimethoate gave over 60% mortality for up to seven days (Mourad, 1996). In Brazil, lambda-cyhalothrin, pirimiphos-methyl, deltamethrin and cypermethrin insecticides were effective in suppressing onion thrips population but only cypermethrin increased yield (Souza-Goncalves, 1996). In Pakistan, monocrotophos scw and cypermethrin were reported as the most effective insecticides for controlling infestations of *T. tabaci* on onions, followed by cyhalothrin, triazophos, methamidophos and fenvalerate (Khan *et al.*, 1995). Field studies carried out in Harvana, India using 10 foliar insecticides indicated deltamethrin and cypermethrin were the most effective against infestation of *T. tabaci* in onions and endosulfan, fenitrothion, dichrorvos, malathion and fenvalerate were less effective. The maximum bulb yield was recorded for cypermethrin (Saini *et al.*, 1989). In Kenya, the pesticides which have been registered for thrips management include acephate (Asetaf), beta-cyfuthrin and chlorpyrifos (Bullock star), lambda-cyhalothrin (Lambdex), methomyl (Lannate 25 WP), spinosad (Tracer 480 sc) and Chlorpyrifos-methyl (Reldan 40 EC) (KARI-Thika, 2006)

The potential of botanical and non traditional pest control products in onion thrips control have not been studied widely. Studies carried out in Pakistan using three botanical treatments namely *Datura alba* Seed Extract Infusion, SEI, *Calotropis procera* Latex Infusion, LI, and *Citrullus colocynthus* Fruit Extract Infusion, FEI indicated that all the three extracts were able to cause mortality of onion thrips at various degrees of significance compared to the untreated control. *Calotropis procera*, LI was found to be the best botanical insecticide giving about

44% thrips control (Malik, 2005). Neem (*Azadirachta indica* (Juss)) seed extract was reported to inhibit the growth of onion thrips nymphs (Klein *et al.,* 1996). Carvacrol, a constituent of essential oils was found to have a pronounced deterrent effect on the oviposition site selection of *T. tabaci* (Sedy and Koschier, 2003). Studies indicated that repellent and/or deterrent essential oils from Rosemary (*Rosmarinus officinalis* L.), Marjoram (*Origanum majorana* L.), Mint (*Mentha arvensis* L.), Lavender (*Lavandula angustifolia* L.) and Sage (*Salvia officinalis* L.) combined with other control measures against *T. tabaci* may contribute to the enhancement of biological or integrated management strategies (Koschier and Sedy, 2003). Laboratory trials on the effects of a juvenile hormone analog, pyriproxyfen showed that it had some lethal effects on thrips larvae (Liu, 2003).

Although pesticides provide the most effective means of reducing pests populations, their use should be kept to a minimum because of their many side effects. The problem of insecticide resistance, incompactibility with biological control agents and the risk of chemical residues are some reasons for minimizing pesticide use (Sithanantham *et al.,* 2004). Resistance management is crucial to prolong the effectiveness of insecticides for control of onion thrips. The most important means of managing resistance is to limit insecticide use, making applications only when necessary. Alternation of insecticides with different modes of action would also help to prolong insecticide effectiveness under most conditions (Cranshaw, 2004). The decision to use an insecticide or any other pest control measure requires an understanding of economic or action threshold. An action threshold is the level of pest infestation or damage at which some action must be taken to prevent any economic loss (Hoffmann and Frodsham, 1993). Economic thresholds vary considerably for each combination of crop growth stage, plant part attacked, pest season and climate (Parrella and Lewis, 1997). There are many examples of economic injury thresholds documented for onion thrips on onion crop. Alston and Drost (2008) reported that a threshold of 15 thrips per plant in Utah should prevent economic loss during the early onion bulb growth stage and prevent rapid population build-up. Shelton *et al.* (1987) established an action threshold at three thrips per leaf in New York.

The selection of sampling technique and definition of sampling unit size is of basic importance to sampling plan design and population monitoring (Sithanantham *et al.*, 2004). Thrips sampling is important to optimize management strategies and to inform the grower about thrips population pressure (Alston and Drost, 2008). Sampling procedures applied on onion thrips have been reported in different parts of the world (Palmer *et al.*, 1989; Lewis, 1997; Mound and Kibby, 1998). Use of traps was reported as one of the most commonly used method (Salifu *et al.*, 1987, Lewis, 1997). Blue sticky traps smeared with insect glue (poly-isobutylene) were reportedly most preferred by onion thrips (Guzman *et al.*, 1996; Lewis, 1997). The blue traps were the most attractive compared with white, green, yellow, grey and red traps, while the black traps caught no thrips (Lu, 1990). An effective sampling method for pest management decisions is *in situ* counts where the neck of onion plant is opened and the number of thrips adults and larvae quickly counted before they disperse or hide (Alston and Drost, 2008). Tong-Xian (2002) reported that the whole-plants sampling with absolute numbers of *T. tabaci* on onion plants, was the most accurate method but the most time consuming.

### 1.2.4 Onion Production Practices

Although onions are grown in a wide range of agro-ecological zones in Kenya, yields are generally very low (Kimani and Mbatia, 1993). The low production of onions is mostly attributed to poor crop management practices (Karel and Mueke, 1978; Waiganjo *et al*., 2002). The standard or recommended onion crop production practices that would greatly help to keep onion plants healthy, manage pests and diseases, enhance yield and quality and and improve farm income to farmers are discussed below.

#### 1.2.4.1 Soils and Soil pH

Onions grow well in well-drained, friable silty or sandy loam soils with high level of organic matter and good water holding capacity (KARI, 2006). A soil pH range of 6.0 to 6.5 is ideal. Periodic soil fertility evaluation through soil sampling and testing is usually an important practice as the results are used as a guide in the application of manures and fertilizers.

#### 1.2.4.2 Land Preparation

Land preparation is an important initial operation in growing of any crop. During land preparation it is important to eradicate all the weeds. Effective weed control often has been more difficult to obtain in onions than in many other crops because the crop grows more slowly and therefore is less competitive than weeds. Herbicide options are also more limited in onions compared with other row crops (Culpepper, 2002).

#### 1. 2.4.3 Planting

Onions are grown either by broadcasting, which is the easiest way (Hassan and Malik, 2002) or by transplanting, which results in good yield (Hassan and Malik, 2001 b). In Kenya onions are mainly propagated by transplants raised in nursery beds (KARI, 2006). Transplanting is usually done in rows. The cultivation of onions in rows has a positive impact on yields up to certain limits (Malik, 2005).

#### 1.2.4.4 Onion Spacing

The spacing of a crop is determined by many factors including the fertility levels of a given soil. It is important to use the recommended spacing of a crop in order to have the correct plant density or population. In Kenya, the recommended optimum inter-row and intra-row spacing of onions is 30 cm and 8-10 cm respectively (KARI, 2006). Malik (2005) reported that an inter-row spacing of 25-30 cm with 20 cm between plants was the best combination for transplanted onion for minimizing thrips densities and for the highest yield in the Balochistan province of Pakistan.

### 1.2.4.5 Manure and Fertilizer Use

Onions grow best in fertile well drained soils. Use of inorganic fertilizers and organic manures is a recommended practice in crop production. Fertilizers boost the growing of crops by providing essential plant nutrients and also improving the physical and chemical conditions of a given soil (KARI, 2006; USAID-Kenya, 2007). Onions are heavy feeders and require more fertilizer than is used in most vegetable crops (Boyhan *et al.*, 2002). However, indiscriminate use of inorganic fertilizers may lead to soil infertility by immobilizing certain essential plant nutrients and also altering the pH of the soil thus affecting the availability and proportion of beneficial soil micro-flora and micro-fauna. Fertilizer application should, therefore, always be guided by recent soil sampling and testing (KARI, 2006; USAID-Kenya, 2007).

Many authors have reported the role of fertilizer elements in influencing yield, quality and pest infestation of crops. Fertilizers provide plants with more nutrients (Bogenschutz and Konig, 1976; Bentz *et al*., 1995) as a result of which plants not only get lush green colour but also enhance the accumulation of nutrients in the shoots, which attract phytophagous insects (Natarajan, 1986). Use of fertilizers not only affects the nutritive value of plants but also impacts on the insect pest densities (Dowell and Steinberg, 1990; Bentz and Larew, 1992).

Soil fertility management may affect thrips densities and damage and therefore soil fertility must be considered along with other factors for the IPM of thrips (Rateaver and Rateaver, 1993). According to the same author, lack of adequate soil calcium may invite higher populations of thrips.

Higher nitrogen levels may invite thrips, and the effects of excessive nitrates are compounded by shortages of phosphorus, sulphur, boron and manganese. Nutritional balance can reduce thrips attack (Culpepper, 2002). If too little nitrogen is available, onions can be severely stunted and more susceptible to diseases. High nitrogen rates produce succulent plants that are more susceptible to diseases and to formation of flower stalks. Onions heavily fertilized with nitrogen also do not store well. Excess nitrogen late in the growing season delay maturity and cause double centers formation (Boyhan *et al.*, 2002). The excess use of nitrogen disturbs the balance of soil macro- and micro-nutrients (Malik, 2005). The same researcher noted that fertilizer has no effect on the population of thrips up to an optimal level but if the rates were increased above the optimal level, thrips infestations increased. Conversely an increase in fertilizer use beyond optimal level lead to a decrease in onion yield according to Malik (2005).

#### 1.2.4.6 Weed Control

Weed control is an unavoidable operation for successful production of vegetable crops including onions. Weed control is one of the most important production practices in farm management (Aness, 1994). Production losses increase with weeds infestation. Such losses may arise mainly from the competition between crops and weeds for light, water, space and nutrients. Weeds compete with crop plants more at very early growth stages (Jilani *et al., 2003*). Usually, farmers do not weed early enough to prevent major damages due to this competition (Defoer and Nieuwkoop, 1991). The weed problem is becoming worse in irrigated areas where cropping intensity is rapidly increasing and weed management through cultivation practices has become a challenge. The fixed crop rotation has encouraged the establishment of permanent weed flora, with large seed reserves in the soil (Anonymous, 1998). Because of slow growth, small stature, shallow roots, and lack of dense foliage cover, onion seedlings cannot withstand competition with weeds (Appleby, 1996). Whereas onion yield losses from 49% to 86% have been reported from India due to weed interference (Lagoke and Sinha, 1983), losses up to 96% have been reported from United Kingdom (Bond and Burston, 1996). The critical weed competition is up to 40 days after transplanting (Rajendra *et al*,. 1986). In onion plots where weeds were uncontrolled, yield was shown to decrease by 54% compared to weed free onion plots (Khurana *et al*., 1986).

Jilani *et al.* (2003) showed that weed population was significantly reduced by different weed control measures. The report further indicated that hand weeding three times was superior to use of herbicides in decreasing weed densities and also giving the highest yield. Different weed control measures also significantly affected bulb diameter. Weed management studies conducted in transplanted onion in Islamabad, Pakistan, showed that weed competition resulted in 71 to 76% reductions in marketable bulb yield. Herbicide application at 2 DAT in combination with one weeding at 60 DAT were found more effective in enhancing marketable bulb yield and recorded higher returns than other treatments in Pakistan (Khokhar *et al*., 2005). Herbicides registered for use in onions in Kenya include (Afalon 50 WP (Limuron), Stomp 500 EC (Pendimethalin) and Ramrod Flowable 480 (Propachlor) (KARI-Thika, 2006). In a survey conducted in Kenya, Waiganjo (2004) reported that weed control was the third most perceived challenge in the production of onions in the country. Malik (2005) reported that hand weeding is an expensive input which erodes the profit margin of the farmer and that herbicides can be used to reduce the capital used in weeding.

Weed destruction in onion field and surrounding margins can help to reduce thrips population since weeds act as alternative hosts and re-infestation sites for thrips (Roberts, 1973; Hassan and Malik, 2001 a, b, and 2002; Culpepper, 2002). Weeding of onion fields should be done regularly and as necessary to avoid competition and curb pests and diseases (USAID- Kenya, 2007). Weeding should cease towards the end of the season and one month before harvest soil should gently be removed from the bulbs (KARI, 2006).

#### 1.2.4.7 Irrigation

Onion crop has a shallow root system and needs frequent irrigation after short intervals especially during the first three months after transplanting. The crop cannot, therefore, withstand any prolonged drought without sacrificing yield and quality.

Field experiments carried out to evaluate the effects of irrigation intervals on growth and yield of onion varieties Swat-1 and Phulkara indicated that five days irrigation interval was appropriate for proper survival and growth of onion seedlings (Khan *et al.*, 2005). Prolonged frequent irrigation during the maturation stage of the crop may promote the formation of double bulbs which are of low marketable quality. It may also lower shelf-life of onion bulbs in storage (Culpepper, 2002).

A number of studies on the effects of irrigation on growth, pest control and yields on onions have been conducted. According to Bevacqua (2002), managing, timing and amount of water applied during irrigation are critical in onion production. Light frequent watering of the crop is recommended. Irrigation efficiency in onion production may be improved by scheduling water applications to match as closely as possible the evapotranspiration needs of the crop, designing irrigation systems for maximum uniformity and embracing a maintenance plan that ensures continued high efficiency (Burt, 2001; Bevacqua, 2002). Drought stress increases the susceptibility of onions to thrips damage and adequate irrigation throughout the growing season is a critical factor in minimizing thrips damage (Fournier *et al.*, 1995). Natural rainfall is one of the best thrips control factors (Brad, 2002).

Furrow irrigation is the least efficient method of irrigation since to ensure adequate irrigation uniformity in all areas; some portions of the field will be overirrigated (Garcia *et al*., 1999). Sprinkler irrigation permit frequent application of small amount of water, which is ideal for seed germination and early crop growth. It can be used to deliver water on sloping grounds but wetting of foliage during late season promotes foliar diseases in onions (Bevacqua, 2002). Adopting drip irrigation, which has the potential for high uniformity, is an important step towards greater efficiency. Drip systems tend to be highly efficient because they minimize or eliminate surface runoff, reduce deep percolation and eliminate the need to overirrigate some parts of the field (Bevacqua, 2002).

#### 1.2.4.8 Onion Pests and Disease Control

Thrips are the major pests of onion, garlic and leek in Kenya (Singh, 1983). The stage of growth when an infestation occurs seems to determine the extent of yield loss. In onions, it appears that early and late-season infestations diminish yields less than those occurring in mid-season during the bulbing stage (Fournier *et al*., 1995).

In a survey conducted in onion growing areas in Kenya, many farmers perceived onion pests and diseases as the most serious production impendiments (Waiganjo, 2004). Some of common diseases attacking onions include: Downy mildew, Purple blotch, fungal and bacterial bulb rot and Damping off disease (Boyhan *et al.*, 2002; Regina Seeds, 2004; Waiganjo, 2004; KARI, 2006; USAID-Kenya, 2007). Some of the chemicals registered in Kenya for the control of onion diseases include Dithane M45 (Mancozeb), Equation PRO (Famoxadine and Cymoxanil), Alietle 80 WP (Fosetyl- Aluminium), Milraz WP 76 (Propineb and Cymoxanil), Milthane Super (Mancozeb), Penncozeb (Mancozeb) and Vondozeb 75 DG (Mancozeb) (KARI-Thika, 2006).

The management of crop pests and diseases rarely relies on a single control practice; usually a variety of tactics are integrated to maintain pests and diseases at acceptable levels The control tactics used in integrated pest management include pest resistant or tolerant plants, cultural, physical or mechanical, biological and chemical control. Conservation of environmental quality (air, water, soil, wildlife, and plant life) is an important element of IPM. Practices that maintain environmental quality can conserve natural enemies that may help lower the pest status of target insects. Pest and disease management tactics that minimize environmental impact will contribute to the stability of agricultural systems (Hoffmann and Frodsham, 1993).

#### 1.2.4.9 Harvesting of Onions and Post-harvest Practices

Quality is the most important factor when producing a marketable product. Onion quality is greatly influenced by the practices adopted during and after harvesting. Careful handling of onions to avoid external and internal damage during post-harvest activities is necessary (Boyhan *et al*., 2002).

Onions should be harvested at optimum maturity. Harvest maturity is reached when 20-50% of pseudo-stems lodge. Harvesting may be carried out manually or by use of machines in mechanized farms (Boyhan *et al*., 2002). To ensure maximum quality and extend their shelf-life, onions should be properly cured. Curing may be done naturally or artificially. Artificial curing is better since man is able to control conditions that promote the process (Boyhan *et al*., 2002). Sorting of onions before and during storage is an important quality assuring post-harvest practice. During sorting all diseased bulbs should be removed as they may act as important source of disease inoculums during storage (Boyhan *et al*., 2002, KARI, 2006). Onions should be graded before marketing. Grading consists of sizing and removing rotten, damaged or off-type onions. Onions should be stored in a dry area with good air circulation. Early short-day onions do not store well and should be moved to market within a few days of harvest. Onions growers should check with potential buyers so that the product can be moved out rapidly. Onions should be marketed as soon as possible to avoid losses in storage due to sprouting, rotting and contamination (Boyhan *et al*., 2002).

## 1.3 HYPOTHESES, RESEARCH QUESTIONS, GENERAL AND SPECIFIC OBJECTIVES

### 1.3.1 Hypotheses

i. **$H_o$:** Onion growing farmers in Mwea and Ndia Divisions of Kirinyaga District, Kenya do not experience any production constraints that affect marketable yield.

   **$H_{A}$:** Onion growing farmers in Mwea and Ndia Divisions of Kirinyaga District, Kenya experience many production constraints that affect marketable yield.

ii. **$H_o$:** All onion varieties grown in Kenya are equally susceptible to onion thrips infestation.

**$H_A$:** Onion varieties grown in Kenya have different levels of susceptibility to infestations by onion thrips.

iii. **$H_o$:** There are no growth losses associated with thrips infestations of various onion varieties grown in Kenya.

**$H_A$:** Onion thrips infesting various onion varieties grown in Kenya result in loss of growth of plants.

iv. **$H_o$:** Onion varieties grown in Kenya have the same yield capacity.

**$H_A$:** Onion varieties grown in Kenya do not have the same yield capacities.

v. **$H_o$:** There is no yield loss associated with infestations by thrips of various onion varieties grown in Kenya.

**$H_A$:** Onion thrips infesting various onion varieties grown in Kenya result in loss of yield.

vi. **$H_o$:** There is no relationship between onion thrips infestation density on local onion varieties and pest damage score, foliar disease incidence and bulb quality.

vii. **$H_A$:** There is a relationship between onion thrips infestation density on onion varieties and foliar damage score, foliar disease incidence and bulb quality.

### 1.3.2 Research Questions

i. Do farmers in Mwea and Ndia Divisions follow the recommended practices in the production of onions in order to realize high marketable yield?

ii. Are there any onion varieties grown in Kenya that show less susceptibility to onion thrips infestation?

iii. What losses in terms of number of leaves and fresh weight do onion plants of various varieties suffer as a result of onion thrips infestation?
iv. What are the yield capacities of various onion varieties grown under Mwea and Thika conditions in Kenya?
v. What yield losses are associated with onion thrips infestation of various onion varieties grown in Kenya?
vi. What is the relationship between onion thrips infestation density on local onion varieties and foliar damage score, frequency of foliar disease incidence and bulb quality?

### 1.3.3 General Objective

To assess the bulb onion production practices and constraints experienced by farmers in Kirinyaga District, Kenya and evaluate yield potential and susceptibility of onion varieties to onion thrips.

### 1.3.4 Specific Objectives

i. To determine the management practices carried out by farmers during onion production in Mwea and Ndia Divisions of Kirinyaga District in Central Kenya.
ii. To evaluate the host-plant resistance/susceptibility of the onion varieties to attack by onion thrips.
iii. To evaluate the effects of onion thrips infestation on onion plant growth.
iv. To determine the yield capacities of onion varieties grown under Mwea and Thika conditions in Kenya.

v. To assess yield losses due to onion thrips infestations of various onion varieties.

vi. To elucidate the relationship between onion thrips infestation density on local onion varieties and pest damage, foliar disease incidence and bulb quality

# CHAPTER 2

## 2.0 GENERAL MATERIALS AND METHODS

## 2.1 SURVEY OF BULB ONION PRODUCTION PRACTICES AND CONSTRAINTS IN KIRINYAGA DISTRICT, KENYA

### 2.1.1 Survey Area

A survey to gather information on onion production practices and challenges was carried out in Kirinyaga District which was one of the important onion production areas in Kenya. The district covers an area of about 1,437 square kilometers of which 84 % is arable land (Syagga, 2009). It is one of the seven districts in the Central Province and is bordered by Nyeri and Muranga districts to the west, Mbeere District to the south and Embu District to the east. The estimated human population was 491, 161 (KNBS, 2007).

Kirinyaga District is a high potential area with an annual average rainfall ranging from 888 to 2,200 mm. The average annual temperature range is 9.7 to 21.6°C. In most of the areas the soil are deep and of moderate to high fertility (Jaetzold and Schmidt, 1983). The district has a varied tropical climate, which is influenced by its location within the highlands of Mt. Kenya and near the Equator. Mt. Kenya area in the northwestern part of the district, receives the highest amount of rainfall because of the high altitude. The amount of rain declines from the high altitude towards the lowland areas of Mwea Division, which has low potential.

Administratively, the district is made up of 4 divisions namely: Gichugu, Central, Ndia and Mwea. The pilot survey was conducted in Ndia and Mwea Divisions where onion production seemed to be an important agricultural enterprise. Specifically, most of onion farmers in the district were concentrated in Kibirigwi and Mwea irrigation schemes in Ndia and Mwea Divisions respectively. In the other divisions, onion production was apparently of less importance.

Kibirigwi irrigation scheme is located along Karatina- Sagana road in Kiine location in Ndia Division. It is a small-scale irrigation project. Land ownership is mostly free-hold such that majority of households possessed title deeds for their land. The project which was started in 1975 covers an area of 1,204 acres of which 362 acres are under irrigation. Water is sourced from Ragati River and water distribution is by gravitational flow. Sprinkler irrigation method is the predominant type. Among the main objectives of the scheme were, to establish commercial vegetable production program under irrigation having an estimated target of 600 acres cultivated annually and to introduce the school leavers (youth) into commercial vegetable production, thus self-employment. Onions are among the horticultural crops grown in the scheme and its environs. The scheme is managed by Kibirigwi Farmers Co-operative Society (KIFCO) and a General Manager seconded to the scheme from the Ministry of Agriculture. The scheme was initially meant to cater for about 272 water users but today there are about 737 of them according to a recent survey (Mutange, 2007).

Mwea irrigation scheme is about 100 Km North East of Nairobi. Farming in the scheme started in 1956 and rice has been the predominant crop. The scheme has a gazetted area of 30,350 acres. A total of 16,000 acres have been developed for paddy production. The rest of the scheme is used for settlement, public utilities, subsistence and horticultural crops farming.

The scheme is served by two rivers viz Nyamindi and Thiba. Irrigation water is obtained from intake weirs, conveyed and distributed in the scheme by gravity via unlined open channels. Land tenure is mainly on tenancy basis. Since inception till 1998, the scheme was being run by various government agencies. In 1998, the scheme management was taken over by Mwea Rice Farmers Cooperative Society. However, the society faced a lot of managerial and technical problems and in 2003; the farmers approached the government for assistance in the management of the scheme. Onion production is an important enterprise for a few farmers in the scheme.

### 2.1.2 Target Population, Sampling and Data Collection

The survey targeted rural households which had or were actively involved in commercial production of bulb onions in Mwea and Ndia Divisions. The sample size was made of 42 households selected randomly depending on the accessibility of their farms. To be included in the sample, the targeted households should have been engaged in commercial onion production for at least three years. Forty two onion growing farmers were interviewed. In Mwea where onion farmers were few, the sample size was 11 and all identified farmers were interviewed but in Ndia Division, where onion production was a relatively important enterprise, 31 randomly selected farmers were included in the sample.

A structured questionnaire was prepared and used to gather information from the interviewees (Appendix I). The farmers were visited in their farms. The questionnaire was pre-tested prior to the actual survey in order to assess its strength and weaknesses and necessary adjustments made. Literacy level of the farmers was high but where there was language barrier the questionnaire was interpreted into the local language of the respondent. Questions regarding farmer information such as household type, age, main and secondary occupations, education level, wealth status, agronomy profile, crop protection practices, onion post-harvest practices, annual income from onion sales, onion marketing, knowledge acquired through trainings and field days, farm record keeping, and perceived problems relating to onion production were asked. The information obtained from the farmers was confirmed by direct observations made from the onion farms where possible.

## 2.2 EVALUATION OF ONION VARIETIES FOR YIELD CAPACITY AND SUSCEPTIBILITY TO ONION THRIPS

### 2.2.1 Field Sites

On-farm field trials were conducted at two localities. One station was located at KARI-Mwea (0° 37´ S 37° 20´ E) in Kirinyaga District of Central Province, Kenya. The altitude is 1,158m above sea level. The area receives a bimodal rainfall pattern with an average of 850mm per year. The soils are fertile and of moderate drainage, very deep, dark reddish brown to black, friable to firm, slightly cracking clay with humid top soil (vertisols). The mean temperature is about 21.6°C. The centre is in the cotton agro-ecological zone and is about 100 Km North East of Nairobi, Kenya (Jaetzold and Schmidt, 1983; Appendix II).

The other site was at KARI- Thika (01° 05´S 37° 00´E) with an altitude of about 1,600m above sea level. The area receives a bimodal rainfall pattern with an average of 1,018mm per year. Mean temperature is 19.2°C. The soils are moderately fertile, well drained, deep, and red in colour. The site is in marginal coffee agro-ecological zone and is about 40 Km from Nairobi, in Thika District of Central Kenya (Jaetzold and Schmidt, 1983; Appendix III).

### 2.2.2 Experimental Design and Treatments

A split plot design incorporating unprotected (observation) and protected onion plots were used (plates 2.1a and 2.1b). The two main plots were separated by a distance of 5m to prevent inter-plot influences. In the unprotected onion plot, no pesticides were used to control onion thrips. However, in the protected main plot, thrips were controlled using blanket application of appropriate pesticides.

Pesticides of choice were Malathion 50 EC and Polytrin 440 EC® (Profenofos 400g/l and Cypermethrin 40g/l) applied at rate of 100ml and 40 ml in 20 litres of water respectively. The insecticides were applied on rotation to reduce build up of pesticide resistance and on a weekly basis. The application of insecticides was started two.


**Plate 2.1a:** Experimental plot design at KARI-Thika during the first cropping season


**Plate 2.1b:** Experimental plot design at KARI-Mwea during the first cropping season

weeks after transplanting of onion seedlings. Diseases were controlled in the two main plots using Dithane M45 ® (Mancozeb) at an application rate of 1-1.5 Kg/acre or 50g in 20 litres of water sprayed at 14 days interval. Rindomil Gold Bravo ® (Metalaxyl) was applied every 14 days at a rate of 40g/20l of water but in rotation with Dithane M45 to avoid build up of chemical resistance. Other crop management practices were the same for the protected and unprotected onion plots.

The two main plots were each sub-divided into sub-plots measuring 3mx3m to accommodate the selected onion varieties. The onion varieties were assigned to the plots at random. The plots were replicated four times. All the plots were surrounded by a walking path of 1-1.5m width to facilitate carrying out of crop management practices and also to prevent inter-plot influences

Five bulb onion varieties namely: Bombay Red, BSS 230 Hybrid, Texas Grano, Red Comet and Red Creole were used for the trials (plate 2.2). Red Creole, the most popular variety among onion growing farmers in Kenya was used as local check. The variety is flattened globe shaped and has a shiny red skin with white purplish flesh. It has good storage quality and strong pungent smell. It is also late maturing. Bombay Red is a globe shaped variety with dark red skin colour and white purplish flesh. It has also good storage quality and pungent smell. BSS 230 Hybrid has a dull reddish skin with white purplish flesh. The bulbs are also globe shaped. The leaves are green and with an open architecture. Texas Grano is a globe shaped variety with a yellow or cream skin colour and white yellowish flesh. It has good storage quality but with less strong pungent smell. The variety produces round leaves which are dark






**Plate 2.2:** Onion varieties grown during the trials

green in colour and with an open architecture. It matures early. Red Comet is mostly spindle shaped variety with shiny red skin and white flesh. The leaves are bluish-green in colour and plant has a closed architecture where the leaves at the growing point are closely compacted. It is an early maturing variety. The onion crops were grown for two seasons. Onion seeds for the first season crops were sown in nursery bed on 14$^{th}$ August, 2006 and transplanted at Mwea and Thika trial sites on 28th and 29th September, 2006 respectively. The first season crops coincided with the short rains. The second season crops were sown in nursery on 30$^{th}$ October, 2006 and transplanted at Mwea and Thika field sites on 19$^{th}$ and 21$^{st}$ December, 2006 respectively. The crop was raised during the dry spell. The two season crops at each site were important to assess the effects of weather on thrips population changes.

### 2.2.3 Onion Nursery and Crop Establishment

Onion seeds of the selected varieties were obtained from the local seed market outlets namely: Seminis E. A. Ltd (formally Regina Seeds), Simlaw Seeds (Kenya Seeds) and East African Seeds Ltd. Seeds of each variety were sown in nursery beds each measuring 8m x 1m (plate 2.3). The seeds were evenly drilled in shallow furrows (2cm deep) at a spacing of 15 cm between rows and lightly covered with the soil. Standard onion nursery management practices such as watering; weeding, pests and disease control. Hardening off was also carried out by reducing the frequency of watering. This was necessary for the onion seedlings not to suffer from transplanting

**Plate 2.3:** Mature onion seedlings of various varieties used during the trials

**Plate 2.4:** Transplanting of onion seedlings at KARI-Thika trial site during the first season

shock. Nursery beds were established only at Thika site for ease of management and cost effectiveness. Onion seedlings were transplanted into the main fields when they had developed four true leaves; about 45-50 days after sowing (plates 2.4). Plant spacing was 30 cm between rows and 10 cm within row, so that each sub-plot had a plant population of 300 onion seedlings.

Nutrient status of the soil was determined through random soil sampling and testing at the National Agricultural Laboratories, Nairobi (Appendix IV). Diammonium phosphate (D.A.P.) fertilizer was applied in planting furrows during transplanting at a rate of 200 kg/ha. The crop was top-dressed with calcium ammonium nitrate (C.A.N.) at a rate of 300 kg/ha, one mo/nth after transplanting. Onion crop was kept free of weeds throughout the growing season. Sprinkler irrigation was applied during the first week of crop establishment but this was later discontinued to avoid washing down of thrips. Furrow or basin irrigation was applied instead and when need arose. All other standard crop management practices such as disease control, weeding and irrigation were the same for all the plots. Sampling began at 27 and 14 days after transplanting for the first and second season crops respectively at the two experimental sites. During the first season, sampling was delayed by one week since the crops took a little bit longer to establish.

# CHAPTER 3

## 3.0 SURVEY OF ONION PRODUCTION AND MARKETING PRACTICES IN KIRINYAGA DISTRICT OF CENTRAL KENYA

### 3.1 INTRODUCTION

Enhanced commercial production of bulb onions in Kenya was started in 1950s at Mwea-Tebere and Perkerra irrigation schemes in Kirinyaga and Baringo Districts respectively (Kimani *et al*., 1990). Although onions are grown in a wide range of agro-ecological zones in Kenya, yields are generally very low, ranging between five and 20 t/ha compared to over 30 t/ha recorded for developed countries such as China, Spain and Japan (Kimani and Mbatia, 1993; Nguthi *et al*., 1994; FAO, 1999).

The low yield and poor quality supply of bulb onions from Kenya is attributed to lack of appropriate pest management techniques among other factors (Karel and Mueke, 1978; Muriuki, 1982; KARI/ODA, 1994; Waiganjo *et al*., 2002). In order to find solutions to the low production capacity of bulb onions in Kenya, there is a need to first diagnose the production constraints. These were addressed by carrying out a field survey in Kirinyaga, one of the onion producing districts in Kenya between 29$^{th}$ May, 2007 and 5$^{th}$ June, 2007. In this chapter the findings of the survey are addressed.

### 3.2 MATERIALS AND METHODS

The survey area, target population and sampling procedures and data collection were as described in general materials and methods of chapter two (sub-sections

2.1.1 and 2.1.2). Survey data was entered into a computer immediately after collection and closely checked for accuracy. The data was presented in form of tables and graphs which were prepared using excel computer application software. Descriptive statistics were mainly used to analyse the results. Frequency data involving ranking of important income generating enterprises, weeds and perceived onion production constraints was analysed using Chi-square test (SAS Institute, 2000). A probability level of significance of P= 0.05 was used unless otherwise stated.

## 3.3 RESULTS

### 3.3.1 Background Information of Farmers Growing Onions in the District

Background information about the respondents in terms of age, main occupation, educational level and possession of farm assets in Ndia and Mwea Divisions is contained in table 3.1. In Ndia Division, the age of farmers ranged from 21-79years with an average of about 36 years. The proportions of farmers between the age groups of 21-35, 36-50 and above 50 years were 52%, 42% and 6% in that order. Farming involving both growing of crops and keeping of livestock was widely practised by the respondents (87%) while the rest (13%) were also engaged in other occupations such as casual labour, jua kali artisans and civil service. The results further indicated that of all the respondents in the division, 62% had basic education level, 32% secondary school level, 3% tertially level and 3% had no formal education. It was also evident that majority of the farmers owned knapsack sprayers (90%), dairy cattle (81%) and bicycles (68%). Other farm assets owned in order of decreasing importance included electric power from the national grid and solar panels (23% and 19% respectively), oxen, ox-cart, ox-plough and vehicle (3% each). There was no farmer in the division who owned water pump or tractor.

In comparison, the age of farmers in Mwea Division ranged from 27-56 years with an average of about 42 years. The proportions of farmers between the age intervals of 27-35, 36-50 and above 50 years were 27%, 55% and 18% in that order. Majority of the respondents (91%) were involved in farming while a smaller number (9%) were engaged in other occupations such as casual labour, jua kali artisans and civil service. The survey revealed that many of the farmers (64%) had been educated up to primary school level and 36% had secondary education. No farmers had benefited from tertiary education. Investigations on the type of farm assets possessed by respondents indicated that all had a knapsack sprayer. Like in Ndia, many farmers (64%) owned bicycles and dairy cattle (64%). Unlike in Ndia, many farmers in Mwea had water pumps (82%), oxen and ox-carts (55% each). Other assets owned included ox-ploughs (45%), solar panels (36%), vehicles (27%) and tractors (18%). There was no farmer who had connections of electric power from the national grid.

### 3.3.2 Land Ownership and Use

Information on land ownership and use as reported by the interviewees in the

**Table 3.1:** Background information of respondents in terms of age, occupation, educational background and possession of farm assets.

| **Farmers' background information** | Ndia Division (n=31) | Mwea Division (n=11) |
|---|---|---|
| | % of respondents | % of respondents |
| **Age group of farmer (years)** | | |
| 21-35 | 52 | 27 |
| 36-50 | 42 | 55 |
| 50-79 | 6 | 18 |
| Range | 21-79 | 27-56 |
| Average ($\bar{x}$ ± se) | 36.3 ± 2.2 | 41.8 ± 3.2 |
| **Occupation** | | |
| Farming (both crop and livestock) | 87 | 91 |
| Others(casual labour, business, artisans, civil service) | 13 | 9 |
| **Education background** | | |
| Tertiary | 3 | 0 |
| Secondary | 32 | 36 |
| Primary | 62 | 64 |
| None (informal skills) | 3 | 0 |
| **Possession of Farm assets** | | |
| Knapsack sprayer | 87 | 100 |
| Water pump | 0 | 82 |
| Dairy cattle | 81 | 64 |
| Oxen | 3 | 55 |
| Ox-cart | 3 | 55 |
| Ox-plough | 3 | 45 |
| Bicycle | 68 | 64 |
| Vehicle | 3 | 27 |
| Solar panel | 19 | 36 |
| Electricity (from National Grid) | 23 | 0 |
| Tractor | 0 | 18 |

n- Sample size

study area is indicated in table 3.2. In Ndia Division, the total land size owned by each respondent ranged from 0.25-18.00 acres with an average of 2.63 ± 0.61 acres. In addition, about 39% of them leased land to grow onions and other crops. The land leased by each respondent ranged from 0.13-3.00 acres with an average of 0.26 ± 0.11 acres. The land area under food crops ranged from 0.00-7.00 acres with an average of 0.99 ± 0.28 acres per respondent. The total land utilized for growing food crops in the division accounted for about 34% of the average size of land owned and hired. The total onion acreage ranged from 0.00-0.50 acres and the average was 0.24 ± 0.14 acres per farmer. The total acreage under onions represented about 8% of the average size of land owned and hired. Majority of the farmers (61%) in the division owned title deeds for their land.

In Mwea Division, the total land holding ranged from 0.50-14.00 acres with an average of 4.16 ± 1.45 acres per respondent sampled in the study. Many farmers (56%) leased land to grow onions and other crops ranging from 0.50- 2.50 acres per respondent. The average size of land leased per respondent was 0.52 ± 0.22 acres. The range and average land size under food crops were 0.00- 3.00 acres and 1.10 ± 0.36 acres respectively. The total acreage under food crops accounted for about 24% of the average acreage owned and hired. The land used to grow onions ranged from 0.13-2.00 acres with an average of 0.72 ± 0.21 acres per farmer. The total land under onions was about 15% of the average land holding per respondent. Less than half of farmers (about 46%) in the division possessed title deeds for their farms.

**Table 3.2:** Information on land ownership and use as reported by the respondents

| **Land ownership and use** | **Ndia Division (n=31)** | **Mwea Division (n=11)** |
|---|---|---|
| | % Respondents | % Respondents |
| **Land ownership (acres)** | | |
| Range (acres) | 0.25-18.00 | 0.50-14.00 |
| Average acreage per farmer ($\bar{x}$ ± S.E) | 2.63 ± 0.61 | 4.16 ± 1.45 |
| **Hired land (acres)** | | |
| Farmers hiring land (%) | 38.70 | 55.50 |
| Range | 0.13-3.00 | 0.50-2.50 |
| Average acreage per farmer ($\bar{x}$ ± S.E) | 0.26 ± 0.11 | 0.52 ± 0.22 |
| | | |
| **Land used to grow food crops (acres)** | | |
| Range | 0.00-7.00 | 0.00-3.00 |
| Average acreage per farmer ($\bar{x}$ ± S.E) | 0.99 ± 0.28 | 1.10 ± 0.36 |
| Percent (%) of total land under food crops | 34.26 | 23.50 |
| **Land used to grow onions (acres)** | | |
| Range | 0.00-0.50 | 0.13-2.00 |
| Average acreage per farmer ($\bar{x}$ ± S.E) | 0.24 ± 0.14 | 0.72 ± 0.21 |
| Percent (%) of total land under onions | 8.30 | 15.38 |
| **Farmers with land title deeds (%)** | 61.30 | 45.50 |

### 3.3.3 Income Generating Enterprises

The ranking and chi-square statistics of the most important income generating enterprises in the study area are contained in tables 3.3a and 3.3b. Onion production was significantly rated as the most important income generating enterprise among the farmers interviewed ($\chi^2$ =124.2883; d.f=30; p=0.0001). Other income generating enterprises significantly rated in order of decreasing importance included: French beans, sweet potatoes, tomatoes, kales, cabbages and dairy farming.

### 3.3.4 Land Preparation and Crop Establishment

Some important onion production practices carried out by the farmers are indicated in table 3.4. In Ndia Division, onion seedbed preparation was mainly by hand (81%) using simple hand tools such as jembes and hoes although a few farmers (16%) used ox-ploughs. There were very few farmers who used tractor power (3%) to carry out primary or secondary tillage. All farmers in the division used conventional land preparation method which involved primary, secondary and tertiary operations. Conventional method of establishing onions was also practised by all the respondents where onion seedlings were first raised in nursery beds before being transplanted to the main fields. The conventional or optimal spacing of the crop (30 cm x 8-10 cm) was not widely adopted by the farmers since only 42% used the spacing. Majority of the farmers used less optimal spacing which was either too wide or too close (26% and 32% of respondents respectively). Many farmers used farmyard manure (94%) which was generated in their farms from the livestock kept and there were

**Table 3.3a:** Ranking of the most important income generating enterprises

| Enterprise | Ranking of enterprise | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | 6th | Total |
| | Frequencies(n) | | | | | | |
| Onions | 11 | 14 | 5 | 6 | 0 | 0 | 36 |
| Tomato | 2 | 4 | 4 | 4 | 1 | 1 | 16 |
| French beans | 11 | 7 | 8 | 6 | 2 | 8 | 42 |
| Kales | 2 | 1 | 1 | 5 | 5 | 28 | 42 |
| Sweet potato | 7 | 5 | 11 | 3 | 1 | 15 | 42 |
| Cabbage | 0 | 5 | 3 | 3 | 4 | 27 | 42 |
| Dairy cattle | 1 | 0 | 3 | 5 | 5 | 28 | 42 |
| Total | 34 | 36 | 35 | 32 | 18 | 107 | 262 |

**Table 3.3b:** Chi-square Statistics for ranking of income generating enterprises

| Statistic | Degrees of freedom (df) | Value | Probability |
|---|---|---|---|
| Chi-square ( $\chi^2$ ) | 30 | 124.2883 | < 0.0001 |
| Likelihood Ratio $\chi^2$ | 30 | 149.0437 | < 0.0001 |
| Mantel- Haenszel $\chi^2$ | 1 | 71.0926 | < 0.0001 |
| Phi coefficient | | 0.6888 | |
| Contingency coefficient | | 0.5672 | |
| Crammer's V | | 0.3080 | |

**Table 3.4**: Land preparation and onion crop establishment practices as reported by farmers

| **Onion Production practice** | % of farms | |
|---|---|---|
| | Ndia Division (n= 31) | Mwea Division (n=11) |
| **Land preparation method** | | |
| Manual / human labour | 80.6 | 9.1 |
| Ox-plough | 16.1 | 72.7 |
| Tractor | 3.2 | 18.2 |
| **Method of seedbed preparation** | | |
| Conventional | 100.0 | 100.0 |
| Unconventional (e.g. minimum tillage) | 0.0 | 0.0 |
| **Planting/ transplanting method** | | |
| Conventional | 100.0 | 100.0 |
| Unconventional | 0.0 | 0.0 |
| **Onion spacing adopted** | | |
| Wide spacing (Unconventional) | 25.8 | 45.5 |
| Close spacing (unconventional) | 32.3 | 9.0 |
| Conventional/ optimal (30 cm x 8-10 cm) | 41.9 | 45.5 |
| **Use of farmyard manure during transplanting** | 93.5 | 63.6 |
| **Soil sampling and analysis** | 10 | 9 |

very few incidences where farmers had to buy manure from outside sources. In the division, only 10% of the respondents had taken soil samples from their farms for testing.

Onion production in Mwea Division was semi-mechanized since many farmers (73%) used animal drawn ox-plough for preparing onion seedbeds and only as low as 9% relied on manual labour for this operation. There was appreciable number of farmers (18%) who used tractor power to plough their onion fields in the division. Like in Ndia Division, all the farmers interviewed reported that land preparation involved primary, secondary and tertiary operations. All the farmers first raised onion seedlings in nursery beds before transplanting them onto the main fields. It was also evident that slightly less than half (46%) followed the conventional spacing of the crop during transplanting. Among the farmers using less optimal spacing, majority (46% of respondents) used wider spacing while only 9% used close spacing. Many farmers in favour of close onion spacing argued that it minimized chances of producing low quality colossal and double onion bulbs. About 64% of the respondents used farmyard manure to fertilize their onion seedbeds. Like in Ndia Division, only a few farmers (9%) had taken soil sample from their farms for testing. The reasons given in both divisions for not taking soil samples included lack of information and high costs involved.

### 3.3.5 Weed Control and Irrigation Practices

Weed control and irrigation practices in onion farms as reported by respondents are shown in tables 3.5a, 3.5b and 3.6. Oxalis was significantly rated as the most problematic weed in the onion growing area surveyed ($\chi^2$= 286.0678; d.f = 45; p= 0.0001). Other weeds which were significantly ranked as problematic in order of decreasing importance were Wondering Jew, Nutgrass, Couch grass, Starbur, Double Thorn, Gallant Soldier, Sodom Apple, Pigweed and Mexican Marigold.

In Ndia Division, 81% of the respondents used hand weeding while the rest (19%) combined both hand weeding and herbicides to control weeds in onion fields. Majority of the respondents (87%) weeded their onion plots 2-3 times for each season while the rest (13%) weeded more than three times. From the survey, it was also evident that onions in the division were mainly grown using irrigation and there was no crop that was wholly rainfed. River Ragati was the main source of water for irrigation as it represented 64% of the sources. Gitaga springs were also an important source of water accounting for 36%. Sprinkler irrigation was widely practised where 64% of the respondents were involved. Bucket irrigation was also common as it contributed 32% of the methods. Only 3% of the farmers used drip irrigation. The most popular irrigation frequency was twice per week since it was reported by 64% of the respondents. A sizeable number of farmers (23%) irrigated their onion fields 6-7 times each week. The proportions of farmers irrigating their onion fields once or three times each week were 3% and 10% respectively.

**Table 3.5a:** Ranking of the most problematic weeds in the study area

| Scientific Name | Common Name | Family | Ranking of weed | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1st | 2nd | 3rd | 4th | 5th | 6th | Total |
| | | | Frequencies (n) | | | | | | |
| *Oxalis latifolia* H.B.K. | Oxalis | Oxalidaceae | 24 | 1 | 0 | 0 | 0 | 17 | 42 |
| *Cyperus rotundus* L. | Nutgrass | Cyperaceae | 2 | 9 | 3 | 1 | 0 | 27 | 42 |
| *Digitaria scalarum* (Schweinf) Chiov. | Couch grass | Gramineae | 2 | 9 | 3 | 0 | 1 | 27 | 42 |
| *Commelina benghalensis* L. | Wondering Jew | Commelinaceae | 3 | 3 | 8 | 4 | 1 | 23 | 42 |
| *Acanthospermum hispidium* DC. | Starbur | Compositae | 2 | 0 | 1 | 1 | 1 | 37 | 42 |
| *Galisonga parviflora* Cav. | Gallant Soldier | Compositae | 0 | 5 | 8 | 8 | 5 | 13 | 39 |
| *Solanum incanum* L. | Sodom Apple | Solanaceae | 0 | 1 | 0 | 1 | 2 | 38 | 42 |
| *Tagetes minuta* L. | Mexican Marigold | Compositae | 0 | 0 | 1 | 1 | 4 | 36 | 42 |
| *Amaranthus hybridus* L. | Pigweed | Amaranthaceae | 0 | 0 | 3 | 4 | 8 | 27 | 42 |
| *Oxygonum sinuatum* (Meisn.) Dammer | Double Thorn | Polygonaceae | 1 | 2 | 1 | 2 | 0 | 35 | 41 |
| Total | | | 34 | 30 | 28 | 22 | 22 | 280 | 416 |

**Table 3.5b:** Chi square statistics for ranking of most problematic weeds

| Statistic | Degrees of freedom (df) | Value | Probability |
|---|---|---|---|
| Chi-square ( $\chi^2$ ) | 45 | 286.0678 | < 0.0001 |
| Likelihood Ratio $\chi^2$ | 45 | 229.0968 | < 0.0001 |
| Mantel- Haenszel $\chi^2$ | 1 | 54.4749 | < 0.0001 |
| Phi coefficient | | 0.8293 | |
| Contingency coefficient | | 0.6383 | |
| Crammer's V | | 0.3709 | |

**Table 3.6:** Weed control and irrigation practices as reported by the respondents

| Aspects of weed control and irrigation | Ndia Division<br>% of farms (n= 31) | Mwea Division<br>% of farms (n= 11) |
|---|---|---|
| **Method of weeding** | | |
| Hand weeding only | 80.6 | 72.7 |
| Hand weeding and herbicides | 19.4 | 27.3 |
| **Frequency of weeding per crop season** | | |
| 2 times | 25.8 | 18.2 |
| 3 times | 61.2 | 63.6 |
| 4 times | 6.5 | 9.1 |
| 5 times | 0.0 | 0.0 |
| 6 times | 6.5 | 9.1 |
| **Source of irrigation water** | | |
| River (Ragati) | 67.7 | 0.0 |
| Spring (Gitaga) | 32.3 | 0.0 |
| River/canal | 0.0 | 100 |
| **Method of irrigation** | | |
| Bucket | 32.3 | 0.0 |
| Furrow or basin | 0.0 | 100.0 |
| Overhead/sprinkler | 64.5 | 0.0 |
| Drip | 3.2 | 0.0 |
| **Irrigation frequency per week** | | |
| Once | 3.2 | 9.1 |
| 2 times | 64.5 | 81.8 |
| 3 times | 9.7 | 9.1 |
| Others (6 or 7 times) | 22.6 | 0.0 |

Like in Ndia Division, hand weeding was the most common in Mwea Division as it accounted for 73% of the cases. Only 23% of the farmers combined hand weeding and use of herbicides to control weeds in their onion fields. The most widely adopted weeding frequency was three times per growing season as it represented 64% of the farmers. A small proportion of farmers (18%) weeded their onion plots twice per season while even a smaller number (9% each) controlled weeds four and six times per season. In the division, all farmers sourced their irrigation water from Thiba River. Water was distributed in the area by use of huge unlined water channels or canals. All the farmers used furrow or basin irrigation after pumping the water from channels. Majority of the farmers (82%) watered their onion crops twice per week and only a few (9% each) irrigated onion plots once or three times each week.

### 3.3.6 Onion Pests Control

Information on onion pests and their control as reported by the respondents is contained in tables 3.7 and 3.8. In Ndia Division, all the farmers perceived thrips as the most important onion pests observed in their onion fields and this was followed by cutworms (77%), whiteflies (32%), crickets (3%) and others including white ants and root-knot nematodes (6%). Infestation of onion crop by thrips was considered by the farmers as severe (73%) and moderate (18%) for cutworms. Infestation of onion plots by whiteflies and other pests (nematodes and white ants) was reported as severe by minority of farmers (13% and 3% respectively). Infestation of onions by crickets

**Table 3.7:** Common onion pests and their control as reported by farmers in Ndia Division

| Aspects of common onion pest | % of Respondents (n=31) | | | | |
|---|---|---|---|---|---|
| | Thrip | Cutworm | Whitefly | Cricket | Others (white ant, nematode |
| **Perceived importance** | 100.0 | 77.4 | 32.2 | 3.2 | 6.5 |
| **Severity of infestation** | | | | | |
| • severe | 77.4 | 3.2 | 12.9 | 0.0 | 3.2 |
| • moderate | 16.1 | 17.7 | 9.7 | 3.2 | 3.2 |
| • slight | 6.5 | 6.5 | 9.7 | 0.0 | 0.0 |
| **Onion growth stage of attack** | | | | | |
| • Pre-bulbing | 77.4 | 77.4 | 32.3 | 3.2 | 6.5 |
| • Bulbing | 93.5 | 3.2 | 29.0 | 0.0 | 6.5 |
| • Bulb enlargement | 93.5 | 0.0 | 29.0 | 0.0 | 6.5 |
| • Bulb maturation | 83.9 | 0.0 | 29.0 | 0.0 | 6.5 |
| **Pest control practices** | | | | | |
| • Chemical | 100 | 45.2 | 32.3 | 3.2 | 3.2 |
| • Physical/cultural | 0.0 | 25.8 | 0.0 | 0.0 | 0.0 |
| • Biological | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| • None | 0.0 | 6.5 | 0.0 | 0.0 | 0.0 |

**Table 3.8:** Common onion pests and their control as reported by farmers in Mwea Division

| Aspects of common onion pest | % of Respondents (n=11) | | | | |
|---|---|---|---|---|---|
| | Thrip | Cutworm | Whitefly | Cricket | Others (white ant, nematode |
| **Perceived importance** | 90.9 | 63.6 | 18.2 | 9.1 | 18.2 |
| **Severity of infestation** | | | | | |
| • severe | 72.7 | 36.4 | 0.0 | 0.0 | 0.0 |
| • moderate | 18.2 | 27.3 | 9.1 | 9.1 | 9.1 |
| • slight | 0.0 | 0.0 | 9.1 | 0.0 | 0.0 |
| **Onion growth stage of attack** | | | | | |
| • Pre-bulbing | 81.8 | 63.6 | 9.1 | 9.1 | 9.1 |
| • Bulbing | 81.8 | 9.1 | 18.2 | 0.0 | 9.1 |
| • Bulb enlargement | 63.6 | 0.0 | 18.2 | 0.0 | 9.1 |
| • Bulb maturation | 54.5 | 0.0 | 18.2 | 0.0 | 18.2 |
| **Pest control practices** | | | | | |
| • Chemical | 81.8 | 45.5 | 18.2 | 0.0 | 18.2 |
| • Physical/cultural | 0.0 | 0.0 | 9.1 | 0.0 | 0.0 |
| • Biological | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| • None | 9.1 | 9.1 | 0.0 | 9.1 | 0.0 |

was reported as moderate by only 3% of the respondents. According to many farmers (77-94%), thrips attacked onion crop at all stages of growth with the peak being observed during the bulbing and bulb enlargement growth stages. Cutworms were reported as serious pest during crop establishment (pre-bulbing and bulbing growth stages) but were of no threat during later stages of crop growth. Whiteflies were reported to infest onion crop during all stages of crop growth by 29-32% of respondents. Crickets were only observed during the pre-bulbing period according to some farmers (3%). Chemical pest control was the most widely used according to the findings of the survey. The perceived importance of chemicals to control various onion pests was as follows: thrips (100%), cutworms (45%), whiteflies (32%), crickets (3%) and other pests including nematodes and white ants (3%). About 26% of the respondents used physical means to control cutworms but no other pest was managed using the option. A few farmers (6%) did not control cutworms in their farms. Biological pest control such as use of natural enemies of pests was not used by any farmers in the division.

In Mwea Division, thrips were perceived as the most important onion pests (91%) followed by cutworms (64%), whiteflies (18%), crickets (9%) and other pests including nematodes and white ants (18%). Majority of the farmers perceived attack of onion crop by thrips as severe (73%) while infestation of cutworms was mostly rated as moderate to severe (64%). Infestations by whiteflies, crickets and other pests (white ants and nematodes) were reported to be moderate (9% each). Onions were reported to be attacked by thrips during all stages of growth (54-82%) and the peak was observed during bulb formation. Many farmers (73%) reported that cutworms attacked the crop during the pre-bulbing and bulbing growth stages. Whiteflies were perceived by few farmers (9-18%) to invade onion crop during all stages of growth. Crickets were cited as important during the pre-bulbing period by 9% of the respondents. A few farmers (9-18%) reported that other pests including white ants and nematodes were observed at all stages of crop growth. Like in Ndia Division, pesticides were the most widely used strategy to control pests in onion fields. The proportions of farmers using chemicals to control the various common pests were as follows: thrips (82%), cutworms (46%), whiteflies and other pest including white ants and nematodes (18% each). There were a few farmers (9%) who used cultural methods such as clean weeding to control whiteflies. There were no farmers who used biological methods to control pests in onion farms. Results indicated that a few farmers did not control thrips (9%), cutworms (9%) and crickets (9%).

Information on the use of alternative onion pest control options and Good Agricultural Practices (GAP) is shown in table 3.9. In Ndia Division, alternative methods of pest control in onion farms including use of biorationals and biopesticides, wood ash, crop rotation, clean weeding and crop hygiene were used by a few farmers (36%). All the farmers (36%) who used these methods thought that they were of moderate efficacy. Studies to compare awareness and practising of various aspests of Good Agricultural Practices among the onion growing farmers exposed some disparities. These disparities were as follows: integrated pest management (16%), minimum residual levels (3%), traces of pesticide (10%), pest

**Table 3.9:** Alternative onion pests control and Good Agricultural practices (GAP) in onion production as reported by the respondents

| Aspect of onion pest control | Ndia Division % of farms (n= 31) | Mwea Division % of farms (n=11) |
|---|---|---|
| **Use of alternative onion pest control options** ( e.g. use of biorationals and biopesticides, wood ash, crop rotation, clean weeding and crop hygiene) | 35.5 | 27.3 |
| **Efficacy of alternative onion pests control options** | | |
| • Highly effective | 0 | 9.1 |
| • Moderate | 35.5 | 18.2 |
| • Slight | 0.0 | 0.0 |
| **Aware of Good Agricultural Practices (GAP)** | | |
| • Integrated pest management | 80.6 | 81.8 |
| • Minimum residual levels | 96.8 | 90.9 |
| • Post-harvest interval | 100.0 | 90.9 |
| • Treacability of pest control product | 25.8 | 45.5 |
| • Pest scouting | 100.0 | 90.9 |
| • Record keeping of pest management options | 87.1 | 90.9 |
| **Adoption of Good Agricultural Practices (GAP)** | | |
| • Integrated pest management | 64.5 | 63.6 |
| • Minimum residual levels | 93.5 | 81.8 |
| • Post-harvest interval | 100.0 | 81.8 |
| • Treacability of pest control product | 16.1 | 18.2 |
| • Pest scouting | 93.5 | 90.9 |
| • Record keeping of pest management options | 64.5 | 36.4 |

scouting (6%), and record keeping of pest control options (23%)  The least understood and observed practice was testing of pesticide traces since out of 26% respondents who were aware of the practice, only 16% had adopted it.

In Mwea Division, a smaller number of farmers (27%) used alternative onion pest control methods which were thought to be of moderate to high efficacy (9-18%). Farmers in favour of these methods in both Ndia and Mwea divisions cited less toxicity to humans and animals, low cost and less environmental pollution as their main reasons for adopting the measures. The divorce from practice of the various Good Agricultural Practices in the division were as indicated below: integrated pest management (18%), minimum residual levels (9%), post-harvest interval (9%), traces of pesticides (27%) and record keeping of pest management methods (54%). All farmers (91%) who had knowledge on pest scouting carried out the practice. Like in Ndia Division, few farmers (46%) understood the concept of pesticide traces and only 18% had their onions tested for the traces.

### 3.3.7 Onion Diseases and their Control

Details about common onion diseases and their control reported by the farmers are contained in tables 3.10 and 3.11. Disease infection was a major challenge in the production of onions in Ndia Division according to many of those interviewed. Common onion diseases and their perceived importance included Downy mildew, *Peronospora spp.* (90%), Purple blotch, *Alternaria porri* Ellis (74%), bulb rot, (bacterial or fungal) (68%) and Damping off disease, *Pythium sp.* (13%). Infections

**Table 3.10:** Common onion diseases and their control as reported by farmers in Ndia Division

| Aspects of onion disease | % of Respondents (n=31) | | | |
|---|---|---|---|---|
| | Downy mildew | Purple blotch | Bulb rot | Damping off disease |
| **Perceived importance** | 90.3 | 74.2 | 67.7 | 12.9 |
| **Severity of infestation** | | | | |
| • severe | 72.4 | 61.3 | 35.5 | 3.2 |
| • moderate | 19.4 | 6.5 | 19.4 | 6.5 |
| • slight | 0.0 | 0.0 | 9.7 | 3.2 |
| **Onion growth stage of attack** | | | | |
| • Pre-bulbing | 71.0 | 64.5 | 12.9 | 9.7 |
| • Bulbing | 77.4 | 67.7 | 25.8 | 0.0 |
| • Bulb enlargement | 87.1 | 74.2 | 51.6 | 0.0 |
| • Bulb maturation | 74.2 | 71.0 | 45.2 | 0.0 |
| **Pest control practices** | | | | |
| • Chemical | 90.3 | 77.4 | 3.2 | 12.9 |
| • Physical/cultural | 0.0 | 0.0 | 51.6 | 0.0 |
| • Biological | 0.0 | 0.0 | 0.0 | 0.0 |
| • None | 0.0 | 0.0 | 18.2 | 0.0 |

**Table 3.11:** Common onion diseases and their control as reported by farmers in Mwea Division

| Aspects of onion disease | % of Respondents (n=11) | | | |
|---|---|---|---|---|
| | Downy mildew | Purple blotch | Bulb rot | Damping off disease |
| **Perceived importance** | 72.7 | 81.8 | 36.4 | 0.0 |
| **Severity of infestation** | | | | |
| • severe | 36.4 | 63.6 | 18.4 | 0.0 |
| • moderate | 18.4 | 18.4 | 18.4 | 0.0 |
| • slight | 9.1 | 18.4 | 9.1 | 0.0 |
| **Onion growth stage of attack** | | | | |
| • Pre-bulbing | 36.4 | 45.5 | 9.1 | 0.0 |
| • Bulbing | 63.6 | 63.6 | 9.1 | 0.0 |
| • Bulb enlargement | 63.6 | 81.8 | 27.3 | 0.0 |
| • Bulb maturation | 54.5 | 72.7 | 27.3 | 0.0 |
| **Pest control practices** | | | | |
| • Chemical | 63.6 | 72.6 | 9.1 | 0.0 |
| • Physical/cultural | 0.0 | 0.0 | 18.2 | 0.0 |
| • Biological | 0.0 | 0.0 | 0.0 | 0.0 |
| • None | 9.1 | 9.1 | 9.1 | 0.0 |

by Downy mildew and Purple blotch were considered severe by many farmers (72% and 61% respectively) while an attack by bulb rot was taken to be moderate to severe (55%). Damping off disease was reported to be moderately serious by a few farmers (6%) and was confined to onion nurseries. Majority of farmers (64-87%) reported that Downy mildew and Purple blotch invaded the crop as early as at the seedling stage and the diseases progressed, reaching the peak during bulb enlargement stage before declining as the crop approached harvesting stage. Infection by bulb rot was reported by farmers to start immediately after transplanting (13%) and reached the peak during bulb enlargement stage (3 months after transplanting) (51%) before slightly reducing as the crop matured (45%). Damping off disease only affected seedling stage of onion crop according to some farmers (10%). Like in arthropod pest control, chemicals were mainly used to control diseases in onion farms. The proportions of farmers using the method were as indicated below: Downy mildew (90%), Purple blotch (77%), Damping off disease (13%) and bulb rot (3%). Slightly more than half (52%) of the farmers used cultural method (crop hygiene and uprooting of affected plants) to control bulb rot while another 18% did not control the disease. There was no report of any farmer using biological methods to control diseases.

In Mwea Division, onion diseases reported by farmers in order of importance included Purple blotch (82%), Downy mildew (73%) and bulb rot (36%). Purple blotch (73%), Downy mildew (54%) and bulb rot (37%) were reported to have moderate to severe effects on the growth of onion crop. Like in Ndia area, farmers

(36-82%) reported that Downy mildew and Purple blotch invaded the crop as early as at the seedling stage and the diseases progressed, reaching the peak during bulb enlargement stage before declining as the crop approached harvesting stage. Infection by bulb rot was reported by farmers to start immediately after transplanting (9%) and peak during bulb enlargement and maturation stages (3-5 months after transplanting) (55%). Damping off disease was not common at Mwea. Like in Ndia, many farmers (64-73%) heavily relied on chemicals (fungicides) to control Downy mildew and Purple blotch while only 9% used the tactic on bulb rot. A sizeable number of farmers (18%) used cultural methods to control bulb rot. A few farmers (9% each) did not use any method to control Downy mildew, Purple blotch or bulb rot in the division.

### 3.3.8 Harvesting and Post-Harvest Practices and Marketing of Onions

Information on harvesting, post-harvest practices and marketing of onions as reported by farmers is contained in tables 3.12. In Ndia Division, 87% of the farmers used lodging of pseudo-stems as a sign of harvest maturity while the remaining 13% used the age of the crop to determine when to harvest. Many farmers (77%) cured their onions by either sun-drying in the field (42%) or by by spreading on the floor of a cool dry shed or house (35%). Sorting was a common practice by farmers (90%) and the criteria used included size of bulbs (39%), bulb colour (3%) and freedom from pests and diseases (81%). Majority of the farmers graded onions and sold them in two grades (71%) by mixing the jumbo (colossal) and medium grades to form one

**Table 3.12:** Harvesting, post-harvest practices and marketing of onions as reported by respondents in the study area

| | **Ndia Division** % of farms (n= 31) | **Mwea Division** % of farms (n= 11) |
|---|---|---|
| **Signs of harvest maturity** | | |
| • lodging of pseudo-stem | 87.1 | 90.9 |
| • age of crop | 12.9 | 0 |
| • size of bulb | 0 | 9.1 |
| **Curing of onions** | | |
| • respondents involved in onion curing | 77.4 | 90.9 |
| **Methods of onion curing** | | |
| • Spread on floor of cool dry shed or house | 35.5 | 90.9 |
| • Sun-drying in field | 41.9 | 0 |
| **Sorting of onions** | | |
| • farmers carrying out sorting | 90.3 | 100.0 |
| **Criteria for sorting** | n= 31 for each aspect | n= 11 for each aspect |
| • size | 38.7 | 72.7 |
| • colour | 3.2 | 9.1 |
| • pests and diseases attack | 80.6 | 100.0 |
| **Onion grades** | | |
| • 2 grades | 70.9 | 45.5 |
| • 3 grades | 29.1 | 54.5 |
| **Onion buyers** | n= 31 for each aspect | n= 11 for each aspect |
| • local traders/brokers | 83.8 | 100.0 |
| • co-operative societies | 9.7 | 0.0 |
| • direct consumers/ institutions/hotels | 6.5 | 36.4 |
| **Market arrangement with buyers** | | |
| • -cash payments | 96.8 | 100.0 |
| • contractual payments | 3.2 | 0.0 |
| **Specific market demand** | | |
| • good onion grade | 67.7 | 72.7 |
| • proper onion curing | 19.4 | 0.0 |

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grade and the small sized bulbs as the second grade. The rest (29%) of the respondents sold their onions in three grades. Local traders or brokers formed the bulk of the onion buyers (84%) while co-operative societies (10%) and direct consumers including hotels and institutions (6%) were less important. The main method of disposal was by cash payments (97%) while only 3% sold onions by contractual payments. Majority of the buyers (68%) insisted on good grade while a few (19%) demanded properly cured onions. Onions of high quality were given highest premium in the market.

In Mwea Division, 91% of the farmers relied on the collapse of pseudo-stems as a sign of maturity of onions for harvest. Only 9% were guided by the size of the bulbs to initiate harvesting. Onion curing was widely adopted in the area (91%) where spreading of onions on a dry house or shed was the only method used (.91%). Sorting of onions were carried out by all the farmers using mainly freedom from pests and diseases (100%) and size of bulbs (73%) as the criteria. Slightly more than half (54%) sold onions in three grades while the remaining 46% marketed them in two grades. All the farmers sold onions to local traders or brokers although a few of them (36%) also sold to direct consumers including hotels and institutions. Market transactions were through cash payments and majority of the buyers insisted on good grade as a condition for offering favourable onion prices.

The harvesting season for onions and the average market price offered to farmers is shown in table 3.13. Results indicated that onions were planted and sold throughout the year. However, many farmers sold their onions on April (36%), May

**Table 3.13:** Harvesting season of onions and average onion price trends as reported by farmers in the study area

| | **Study Area (Ndia and Mwea Divisions** |
|---|---|
| **Harvesting season for onions** | **% of farms (n=42)** |
| • January | 11.9 |
| • February | 21.4 |
| • March | 23.8 |
| • April | 35.7 |
| • May | 57.1 |
| • June | 47.6 |
| • July | 19.0 |
| • August | 28.6 |
| • September | 31.0 |
| • October | 21.4 |
| • November | 23.8 |
| • December | 28.6 |
| **Onion average price (±S.E) trends (Ksh/Kg onions)** | |
| • 2005 | 26.36 ± 4.06 |
| • 2006 | 22.31 ± 2.86 |
| • 2007 | 34.45 ± 1.82 |

(57%) and June (47%) and very few of them in January (12%). Considering onion price trends between year 2005 and 2007, the study showed that average market price per Kg of onions decreased from Ksh 26.36 ± 4.06 in 2005 to Ksh 22.31 ± 2.86 in 2006 before rising to Ksh 34.45 ± 1.82 in 2007.

### 3.3.9 Perceived Onion Production Constraints

Information on the the ranking and chi- square statistics of the perceived most important onion production constraints in the study area is shown in tables 3.14a and 3.14b. Onion pests were significantly ranked as the most serious impediment to both quality and quantity production of onions ($\chi^2$=126.2671; d.f=30; p=0.0001). Onion diseases and lack of enough capital were also rated as the second and third most important onion production challenges respectively. Other constraints mentioned in order of decreasing importance were unreliable onion market, weeds, availability of water for irrigation and availability of farm inputs.

**Table 3.14a:** Ranking of the most important onion production constraints in the study area

| Type of weed | Ranking of weed | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | Total |
| Pest control | Frequency | 13 | 15 | 9 | 0 | 0 | 5 | 42 |
| Market for onions | Frequency | 5 | 6 | 6 | 5 | 0 | 20 | 42 |
| Water availability | Frequency | 2 | 1 | 3 | 6 | 1 | 29 | 42 |
| Disease control | Frequency | 8 | 16 | 9 | 5 | 0 | 4 | 42 |
| Farm inputs | Frequency | 2 | 1 | 2 | 1 | 0 | 36 | 42 |
| Weed control | Frequency | 4 | 3 | 5 | 4 | 0 | 26 | 42 |
| Capital availability | Frequency | 6 | 0 | 4 | 3 | 0 | 26 | 39 |
| Total | | 40 | 42 | 38 | 24 | 1 | 146 | 291 |

**Table 3.14b:** Chi square statistics for ranking of important onion production constraints

| Statistic | Degrees of freedom (DF) | Value | Probability |
|---|---|---|---|
| Chi-square ( $\chi^2$ ) | 30 | 126.2671 | < 0.0001 |
| Likelihood Ratio $\chi^2$ | 30 | 138.9826 | < 0.0001 |
| Mantel- Haenszel $\chi^2$ | 1 | 54.4749 | < 0.0001 |
| Phi coefficient | | 0.6587 | |
| Contingency coefficient | | 0.5501 | |
| Crammer's V | | 0.2946 | |

## 3.4 DISCUSSION

Results of the survey indicated that majority of onion growers in Ndia Division were within the age bracket of 21-35 years with an average of 36 years. In contrast, onion farmers in Mwea Division were relatively older since majority of them were within 36-50 years age bracket with an average of 42 years. The participation of young people in onion production reported in Ndia was a welcome move since it created hope for the future survival and success of the enterprise, a conclusion which was held by Malik (2005) who conducted a survey on onion production practices in Balochistan Province of Pakistan. Further, the observation implied that some of the objectives of establishing Kibirigwi Irrigation Scheme in Ndia Division as reported by Mutange (2007) were realized. There was a need to promote onion production in Mwea to make it more attractive to young people.

It was evident from the survey that farming was the main occupation to many of the respondents in Ndia and Mwea Divisions and very few were engaged in off-farm, self or salaried employment such as casual labour, artisans or civil service. The most probable reasons could have been attractive farm income obtained or that many did not have adequate skills and knowledge that were required in other blue or white collar jobs. The latter was more plausible going by the low level of education recorded in the survey area. There was a need to support and promote the occupation to avoid the many problems associated with rural-urban migrations in search of gainful employment, common to young school leavers.

Considering education background of the farmers, it was clear that many in Ndia and Mwea Divisions had basic education and less than half had reached secondary school level. The proportion of farmers with tertiary education was very low in Ndia and none in Mwea. As a result, many farmers lacked the necessary skills and knowledge which would have placed them in advantageous positions for securing white collar jobs. However, the basic education level possessed meant that many were relatively better placed to understand, adopt and benefit from modern methods of farming and technological advancements. Education was reported to be a pre-requisite to technological advancements in farming by K.I.E (2007).

Farm assets were important in assisting farmers to carry out various farm operations more efficiently and effectively. In Ndia Division, many farmers lacked important assets that would promote onion production. It was evident that many lacked reliable sources of farm power. However, many were endowed with assets such as knapsack sprayers, dairy cattle and bicycles. In comparison, apart from owning the above named assets, many respondents in Mwea Division also possessed water pumps, oxen, ox-cart, ox-ploughs and a sizeable number had tractor and vehicle. The absence of reliable sources of power and machinery in Ndia Division limited the degree of mechanization in the area. On the contrary, the level of farm mechanization was higher in Mwea where many farmers used draft animals to carry out various farm operations such as ploughing and transporting of farm produce to the market. The possession of knapsack sprayers by almost all the farmers in Ndia and Mwea Divisions served as a strong pointer to the challenges farmers faced in attempting to manage pests and diseases in their farms and the over-reliance of chemicals in the protection of crops against pests and diseases. This was in agreement with the findings of an earlier survey conducted in the same area where pesticides were reported to be the main pests control tactic in onion farms (Waiganjo, 2004). Results of the survey indicated that many farmers in the two divisions integrated crop production with livestock farming thus benefiting from the interdependence of the two enterprises. This was in agreement with the advantages of mixed farming as outlined by K.I.E (2007). The presence of bicycles in many farms in the two divisions implied that they formed an important means of transport due to their versatility in the observed poorly maintained feeder roads and the less hilly topography of the survey area.

Most of the farmers interviewed in Ndia Division possessed small parcels of land with an average of 2.6 acres per farmer. In contrast, the average land holding in Mwea was 4.16 acres per farmer which was about one and half times higher than in Ndia. Farmers from the two divisions also hired land from the neighbourhood to grow onions and other income generating crops. The percentage of hired land in Mwea was higher than in Ndia. Results indicated that more land was allocated to growing of food crops in Mwea (24% of average land owned and hired) than in Ndia (15% of average land owned and hired). In Ndia Division, onions were allocated about 8% of the average land holding. However, in Mwea land under onions accounted for 15% of the average land holding and this was about one and half times higher than in Ndia. More than half of the farmers in Ndia owned land title deeds compared to less than half of the number in Mwea Division. From these findings, a number of conclusions can be made. Firstly, it was clear that the average land holding in Ndia was lower than in Mwea. The low level of farm mechanization observed in Ndia was most likely as a result of land limitation which made use of farm machinery uneconomical. On the other hand land was more abundant in Mwea and it was, therefore, possible to have some degree of farm mechanization. Secondly, majority of the onion growers in the two divisions were small scale operators. As such, onion production offered a good opportunity for farmers in densely populated areas to utilize small land holdings to grow high value crops. This was effective in reducing levels of poverty in such areas. Thirdly, more land was devoted to growing of food crops mainly maize and beans and little was available for onions. Food security was, therefore, a major pre-occupation among the onion growing farmers in the study area. Finally, lack of land title deeds by many farmers in the study area implied that they could not use land as collateral to secure farm credit from commercial financial institutions to improve on their farm operations. Land tittle deed was important collateral for securing loans as reported by Sakira (1981). In the present study it was evident that many farmers integrated onion production with other income generating crop enterprises. There was, therefore, stiff competition for land and other factors of production among the enterprises. However, diversification was an effective way of reducing risks and uncertainities as pointed out by K.I.E, (2007).

Considering land preparation for onion production, it was clear that the operation was more mechanized in Mwea than in Ndia. This implied that farmers in Mwea were able to carry out the operation more efficiently and effectively than in Ndia. Seedbed preparation in the two divisions involved bush clearing, primary tillage, secondary tillage and tertiary operations This finding meant that farmers did not benefit from the use of other unconventional operations such as minimum tillage and zero tillage which were associated with reduced soil erosion, increased soil moisture conservation and reduced production costs among other benefits. Planting of onions was conventionally done in the two divisions where onion seedlings were first raised in a nursery bed before being transplanted into the main field. This practice was in harmony with the recommended practices in other onion growing areas in Kenya (KARI, 2006). The survey data also indicated that slightly less than half of onion farmers in the two divisions used the crop spacing of 30 cm between rows and 8-10 cm within rows which was in agreement with the recommendations by KARI (2006). However, majority used less optimal spacing which was either too wide or too close. Farmers in favour of more close spacing gave the production of marketable medium sized onion bulbs as the main reason for adopting it. Crop spacing was reported by Malik (2005) to influence onion yield and pest infestation and suggested an inter-row and intra-row spacings of 25-30 cm and 20 cm respectively as the best combination for transplanted onions for minimizing thrips densities and for the highest onion yield in Balochistan Province of Pakistan. Almost all the farmers in Ndia and slightly over 60% in Mwea used farmyard manures generated from their farms to fertilize plots planted with onions. Farmers who did not conform to this practice cited the predisposing role of farmyard manure to onion bulb rot as the main reason. Onions were reported by Boyhan *et al.* (2002) to be heavy feeders requiring more nutrients than was used in many vegetable crops. In other studies by Rateaver and Rateaver (1993), soil fertility management was reported to affect thrips densities and suggested that soil fertility should be considered together with other factors for the integrated management for thrips. Results of the present study indicated that soil sampling and testing was rarely done by onion farmers in the two divisions. Many non-conformists cited lack of awareness as the main reason; a smaller number found no need to carry out the practice while a few others considered it as a costly undertaking. A soil test recently taken in KARI-Mwea, as part of this study, indicated that the soil was strongly acidic and poorly supplied with nitrogen, phosphorus and zinc (KARI-NARL, 2007; Appendix IV). Although the report was not fully representative of the wider survey area, it gave a strong cue of condition of soil in the area which could be followed by further tests. There was a need, therefore, to sensitize farmers in the two divisions to take up this important challenge.

In the present study, many farmers significantly ranked weeds as the fourth most important onion production constraint after pests and diseases, lack of enough capital and unreliable onion market. These findings closely supported the findings of an earlier survey conducted in Kenya where weed control was reported as the third most perceived challenge in the production of onions in the country (Waiganjo, 2004). In another study in India, weeds were reported to be associated with yield losses of 49-

86% and increased incidences of pests and diseases (Logoke and Sinha, 1983). Weed destruction in onion fields and surrounding margins were reported to help in reducing the population of thrips since weeds acted as alternative hosts and re-infestation sites for thrips (Roberts, 1973; Culpepper, 2002, Hassan and Malik, 2002; USAID-Kenya, 2007). Oxalis was significantly rated as the most problematic weed followed by Wondering jew, Nutgrass, Couch grass, Starbur, Double thorn, Pigweed and Mexican marigold. These weeds were considered more important than others either due to their prolific growth rate, high rates of resurgence, abundance, and ability to reduce efficiency of farm workers or their resistance to control through desiccation or by use of herbicides. The method and frequency of weeding adopted had a relationship with yield, onion quality, effectiveness of weed eradication and the profit margins enjoyed by the farmer as reported by Jilani *et al*. (2003), Khokhar *et al*. (2005 and Malik (2005). In the present study hand weeding was the most popular method in the two divisions although a few farmers combined hand weeding and use of herbicides. Majority of the farmers in the survey area weeded their onion crop 2-3 times each growing season and only a few weeded more than three times.

Results of the present survey showed use of sprinklers as the most popular method of irrigating onion fields in Ndia Division. On the contrary, furrow or basin irrigation was the most preferred method in Mwea. The most probable reasons were the good water holding capacity of soils at Mwea, coupled with the more flat topography and availability of adequate water for irrigation. Although sprinkler irrigation was ideal for light frequent watering, and was, therefore recommended for onion crop, the wetting of foliage was found to promote foliar diseases, an observation which was also reported by Bevacqua (2002). Furrow irrigation, a practice which was common in Mwea was reported by Garcia *et al.* (1999) to be the least efficient since to ensure adequate irrigation uniformity in all areas, some portions of the field were prone to over-irrigation. Many farmers in the two divisions irrigated their onion farms two times a week. This frequency was quite low suggesting that there could have been instances when onion crop suffered water stress. Drought stress was reported to increase the susceptibility of onions to damage by thrips and adequate irrigation throughout the growing period was reported by Fournier *et al*. (1995 to be a critical factor in minimizing the damage.

In the present study, pest control was significantly rated as the most important challenge in the growing of onions, a finding that was also reported by Waiganjo (2004) in an earlier survey in the area. Moreover, the presence of knapsack sprayers among many farmers in the survey area served to highlight the importance attached to crop protection activites in the area. In a survey to compare costs and returns of bulb onion production in Kenya and Tanzania, it was revealed that in Kenya, the higher incidences of pests and diseases and higher cost of agrochemicals among other factors were the major impendiments to enhanced onion production (Tschirley, 2004).

Results of the survey revealed that thrips followed by cutworms were perceived as the most important pests in Ndia and Mwea Divisions. Other pests mentioned in order of decreasing importance included whiteflies, crickets and others (white ants and root nematodes). Although whiteflies were mentioned, there was no documented literature that they were pests of onions and their presence could have merely been as a result of presence of weeds in onion farms which acted as alternative host plants. Many farmers perceived infestation of onion fields by thrips as severe but cutworms were reported to have a moderate to severe effect. The few farmers who mentioned whiteflies thought that the pest had moderate to severe effect on onion crop and the same applied to other pests (white ants and nematodes). Infestation by crickets was reported as moderate. The perceived importance of thrips in onion fields was in agreement with findings reported by Waiganjo, (2004) in an earlier study. Results of field trials conducted at KARI-Mwea helped to confirm the above mentioned perception. The stage of growth when a crop was first attacked by any pest or disease was important when devising pest or disease intervention strategy. The stage of attack was also important because it could determine the extent to which yield losses would occur. According to many farmers in the two divisions, thrips attacked onions at all stages of crop growth although the peak was thought to occur during bulb enlargement stage. It was, therefore, important that control measures were initiated early enough before economic injury levels were reached. Consequently training of onion growers on techniques of monitoring infestations by thrips and designing simple methods of determining the best time to control would assist farmers to avoid routine pesticide sprays which were reported in earlier study as the the most common strategy for controlling thrips in onion farms in Kenya (Waiganjo, 2004). Infestations by cutworms were reported to occur during the early stages of crop growth by many respondents in the two divisions. Soil drenching using appropriate chemicals such as furadan was reported by Waiganjo (2004) to assist in control of soil borne pests in onions. Whiteflies and other pests (white ants and root- knot nematodes) were mostly observed during all stages of crop growth while crickets were said to be present only during early stages of crop establishment.

The most popular method of controlling pests on onion fields was by use of chemicals, according to many respondents in the two divisions. A small numbers of farmers used physical and cultural control methods for cutworms and whiteflies. A few farmers considered thrips, cutworms and crickets as of no serious effect to their onion crops to warrant use of any control tactic. There was no mention of the use of biological methods of pest control by the farmers in the two divisions. There was, therefore, a need to sensitize farmers on the use of biological methods of controlling pests and diseases and other methods as part of integrated pest management strategy to reduce over-reliance of chemicals which were not only costly but also harmful to beneficial organisms and the environment. Investigations on alternative options of onion pest control including birationals and biopesticides, woodash, crop rotation, clear weeding and crop hygiene were only important to less than half of those interviwed. Majority of these farmers cited the alternative methods as of moderate efficacy which was in agreement with the findings of Malik (2005) in a study carried out in Pakistan. There was a need to develop effective pest and disease control methods such as use of biopesticides and other bio-intensive integrated pest management technologies and equip farmers with training opportunities and access to information on how to produce and supply safe agricultural produce for both domestic and regional markets. In Kenya, national food safety was reported by GoK (2007) as an important pillar of continued development of the agricultural sector.

Studies to investigate the adoption rates of Good Agricultural Practices (GAP) by onion growers in the two divisions revealed that there existed some disparities between knowledge (awareness) and adoption of various aspects of these practices. The dissonance levels in various aspects of GAP in the two divisions in order of decreasing importance included record keeping for onion pest control options, testing for pesticide traces in onion bulbs, integrated pest management, minimum residual levels, post-harvest interval and pest scouting. It was, therefore, clear that most farmers understood and practised pest scouting, post-harvest intervals and minimum residual levels. However, the most poorly and practised concept was testing for pesticide traces in agricultural produce. Although many farmers were well grounded in knowledge of record keeping of pest control options, a relatively large number of these farmers did not keep any of these records. There was, therefore, a need to address the areas that showed the highest disparities.

Results of the present study indicated that Downy mildew, Purple blotch, bulb rot and Damping off disease in that order were the most serious diseases of onions in Ndia and Mwea Divisions. However in Mwea, Purple blotch, Downy mildew and bulb rot in that order were mentioned as the most prevalent. There was no mention of Damping off disease in the area, perhaps because the hot weather and controlled frequency of watering of seedlings due of presence of clay soil discouraged the spreading of the disease. The importance of Downy mildew and Purple blotch in the survey area was in agreement with the findings of an earlier study by Waiganjo (2004). Apart from Damping off disease which was perceived to attack onion seedlings mosly in nurseries, all other pests were reported to affect onion crop during all stages of growth. It was, therefore, important that control measures be initiated immediately the symptoms appear to avoid economic crop losses. Like in arthropods pest control, chemicals were the most popular method of disease control. The most widely used chemicals were Milraz, Dithane M45, Ridomil and Antracol. Cultural methods including crop rotation and hygiene were also used to control bulb rot in the two divisions. A few farmers, mostly in Mwea did not control Downy mildew, Purple blotch and bulb rot as they did not pose a major challenge in their farms.

It was quite evident from the present study that onions were harvested at the right time, when they attained optimum maturity. It, therefore, meant that many farmers were able to avoid post-harvest losses associated with too early or too late harvesting suggested by Boyhan *et al*. (2002). Natural curing of onions was a widespread practice in the two divisions. The methods of curing in the two areas involved both sun-drying in the field and spreading the bulbs on floor of a dry, well ventilated shed or house with occasional turning of bulbs. Onion curing was a recommended practice in onion production since it was reported by Boyhan et al. (2002) and KARI (2006) to enhance the shelf life of onion bulbs. Sorting was also an important post-harvest activity carried out by many onion growers in the two divisions. It involved removal of all diseased onion bulbs which would have otherwise acted as source of disease inoculums during storage. This was consistent with records of other authors (Boyhan *et al.*, 2002; KARI, 2006). The other criterion for sorting which was widely by farmers in Mwea Division was the size of onion bulbs. A small number of farmers also used the colour of onion bulbs as a basis for sorting. Majority of respondents in Ndia Division marketed their onions in two grades where colossal or jumbo and medium grades were grouped together and the rest sold as small grade. However, in Mwea Division, onions were mostly disposed off in three grades namely: colossal, medium and small grades which were in agreement with the recommendations by Nguthi et al. (1994). In the two divisions, local traders or brokers formed the bulk of onion buyers. Direct buyers including hotels and institutions and Co-operative societies were less important onion market outlets. In absence of other major players in the market there was a possibility of buyers colluding to deliberately lower the onion market price especially during periods of high supply. It was also established that many farmers sold their onions from April to June and very few of them in January. From the results it was possible to conclude that there were more onions reaching the market in the above mentioned months thus depressing the market prices. The price fluctuations experienced between 2005 and 2007 were most likely due to erratic supply of onions in the market. There was, therefore, a need for farmers to spread their onion growing seasons or invest in better onion storage technologies in order to even out demand and supply of onions throughout the year. This would translate into stable onion market prices and income for the farmer. There was also a need for farmers to join

Co-operative societies to enhance their bargaining power during purchasing of farm inputs and onion marketing. Fragile onion market was rated by many farmers in the two divisions as one of the most serious obstacles to quality and quantity production of onions, a view that was also held by farmers in the same area in an earlier study by Waiganjo (2004). These constraints had contributed to dwindled and erratic onion production in the area under study inspite of its promotion since 1950s reported by Kimani and Mbatia (1993).

In conclusion, it was evident from the present study that there existed in the study area some disconnection between the recommended onion production practices and farmer practices. There was, therefore, a need to bridge the gaps in knowledge and skills possessed by farmers in order to raise onion production in the area. This would call for timely intervention strategies by all stakeholders.

## CHAPTER 4

# 4.0 EVALUATION OF SUSCEPTIBILITY OF BULB ONION VARIETIES TO INFESTATIONS BY ONION THRIPS IN KENYA

## 4.1 INTRODUCTION

Pests have been reported to the most important production constraint often causing substantial yield losses in all onion growing areas in Kenya (Tschirley et al., 2004; Waiganjo, 2004). Onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) has been recorded as a major pest of onions in Kenya (Waiganjo *et al.*, 2002). Western flower thrips, *Frankliniella occidentalis* Pergande has also been found infesting onions particularly in Kirinyaga District in Central Kenya (Waiganjo, 2004). Other invasive species of thrips associated with onions in Kenya but thought to be of less economic importance include Cotton bud thrips, *Frankliniella schultzei* Trybom, Bean flower thrips, *Megalurothrips sjostedti* Trybom, Gladiolus thrips, *Thrips simplex* Morison and the Predatory thrips, *Aelothrips sp.* (Stiller, 2001; Waiganjo, 2004). Thrips cause damage to onions by abrading plant tissues and sucking up plant sap which result in localized tissue necrosis (Coviello and McGiffen, 1995). Feeding injuries also predispose plant tissues to subsequent invasion by bacterial and fungal pathogens (Lewis, 1997). Insect pest population changes are influenced by biotic and abiotic factors including trophic influence on the host plant (Sithanantham *et al.,* 2004). Biotic factors include the host plant characteristics among others (Lewis, 1997). Domiciano *et al.* (1993) while studying the association of population fluctuation of thrips on onion with climatic factors reported that maximum temperature of 20-29$^{o}$ C, together with absence of rainfall favoured rapid increase in number of thrips. They also reported a negative correlation between the population of thrips and relative humidity and a positive correlation with temperature. Some onion cultivars have been reported to resist infestation by *T. tabaci* (Lewis, 1997; Mohammad *et al.*, 2004). In a study conducted in Kenya by Waiganjo (2004), Red Creole, Bombay Red, Texas Grano, Tropicana F1 Hybrid and Sivan were reported to be the most commonly grown onion varieties with Red Creole topping the list. The popularity of Red Creole was most likely due to its shiny red bulbs and its strong pungency which were considered as important factors for onion bulb quality. Although the above mentioned varieties were the most common, knowledge of their levels of susceptibility to attack by onion thrips was scanty.

An effective pest management strategy would incorporate host plant resistance among other options. Past efforts in identifying and utilizing host plant resistance in the control of onion thrips in Kenya apparently have been very limited. The objectives of the current research were to identify onion varieties grown in Kenya which were less susceptible to attack by onion thrips, investigate the relationship between onion thrips infestation density and pest damage and incidence of onion foliar diseases. In addition, the relationship between weather variables (temperature and rainfall) and onion thrips density formed part of the study. This chapter gives detailed account of the findings of the above mentioned investigations.

## 4.2 MATERIALS AND METHODS

### 4.2.1 Experimental Design and Treatments

Field trials to assess the susceptibility of onion varieties grown in Kenya to attack by onion thrips were carried out at KARI-Mwea and KARI-Thika sites during two cropping seasons, from August, 2006 to March, 2007. Details of the experimental design and treatments were as described in chapter two, sub-sections 2.2.2 and 2.2.3.

### 4.2.2 Sampling and Extraction of Onion Thrips

The population of onion thrips on onion plants was monitored on a weekly basis from the second or third week after transplanting until the crop showed signs of harvest maturity. The absolute density estimation method involving cutting and bagging of whole plants reported by Freuler and Fischer (1984) was used. During sampling, a self-locking polythene bag was inverted onto a sampled onion plant and then cut at the leaf base using a sharp knife or secateur and taken to the laboratory for extraction, counting, recording and identification of onion thrips. Two crop rows from each side of the sub-plot were used for destructive sampling after leaving one row on each side of the plot and about 30 cm each from the other two edges. This consideration was important because thrips tended to accumulate along the edges of the plot as reported by Dent (1991). Ten consecutive plants selected at random were used for each sampling. Generally, adult onion thrips were more mobile than the larval forms and in order to capture the highest number, it was imperative that sampling be done in the cool morning before 11.00 a.m when they were less mobile.

In the laboratory, onion thrips were dislodged using the extraction method described by Bullock (1963) but with slight modifications. Each sampled onion plant was washed in clean water in 500 ml transparent plastic containers and shaken vigorously. Onion leaves were separated using a pair of forceps and swirled to dislodge the thrips. Thrips in water were then filtered using a clean, white muslin cloth whose mesh size was small enough (about 125 micrometres) not to allow onion thrips to pass through. The cloth was formed into a concave shape and secured onto the plastic container by use of rubber rings or bands. The thrips collected were counted with the help of a hand lens (magnification x10) and no metallic grid was used to assist in the counting since the numbers of thrips were not too many. Larval forms and adults were counted separately for each sampled plant using tally counters and their numbers recorded separately from each plant in well prepared data sheets. Some adults were preserved in 60% alcohol for later identification using identification keys documented by Palmer *et al.* (1989); Mound and Kibby (1998) and Stiller (2001).

### 4.2.3 Morphological Features and Maturity of Onion varieties

Morphological features of each onion variety including architecture and colour of leaves colour of onion bulbs and relative maturity period to harvest were observed and recorded for confirmation using the documented features. Lodging of pseudo-stems of many onion plants was used as a sign of the crop's readiness for harvest.

### 4.2.4 Assessment of Damage by Onion Thrips and Incidence of Foliar Diseases

The evaluation of damage on onion leaves by onion thrips was done by visual examination of the sampled onion plants before extracting the thrips. A damage score of 1-5 as designed by McKenzie *et al.* (1993) was used. The numbers representing the damage score were as follows: 1- no damage (0%), 2- slight damage (≤25%), 3- moderate damage (>25% ≤50%), 4-severe damage (>50% ≤ 75%) and 5-very severe damage (>75%). The presence or absence of fungal disease symptoms on onion leaves of the 10 sampled plants was also noted down. The onion stages of growth as described by Waiganjo (2004) included pre-bulbing stage (0- 30 days or one month after transplanting); bulbing stage (31-60 DAT or two months after transplanting); bulb enlargement stage (61-90 DAT or three months after transplanting) and bulb maturation stage (91-120 DAT or four months after transplanting).

### 4.2.5 Weather data

Weather data was recorded using the facilities and personnel of the meteorological stations located at the two experimental sites. Daily weather parameters measured included rainfall and temperature.

### 4.2.6 Data Analysis

Data was analyzed using Statistical Analysis System program (SAS 8.1; SAS Institute, 2000). Data on number of total onion thrips (larvae and adults), larval and adult thrips, damage score and incidences of onion foliar diseases was subjected to analysis of variance (ANOVA). Data on absolute values of number of thrips and damage score was transformed by $\log_{10}(n+1)$ to obtain normal distribution. The means of number of thrips (larvae and adults), larval and adult thrips, damage score and incidences of onion foliar diseases were separated using Student-Newman-Keuls multiple range test. Excel computer application software was used to calculate means of temperature and total amount of rainfall for each season at each site and also to draw graphs. Probability level of significance of P= 0.05 was used unless otherwise stated.

## 4.3 RESULTS

### 4.3.1 Susceptibility of Bulb Onion Varieties to Attack by Onion Thrips

Results of the trials to evaluate the mean number of onion thrips infesting various onion varieties at KARI-Mwea and KARI-Thika site are shown in tables 4.1 and 4.2. Results indicated that there were significant differences in the mean number of larval thrips between the protected and unprotected onion plots (F= 2241.58, P= 0.0001). A significantly higher number of larval forms of onion thrips were recovered from the unprotected onion plots compared to the protected ones in the two trial sites for the entire experimental period. It was also evident that there were

**Table 4.1:** The pooled mean (± S.E) number of onion thrips recorded from onion plots at KARI-Mwea and KARI-Thika trial sites

| | Treatment | Mean ± S.E number of onion thrips | |
|---|---|---|---|
| a) Larvae | Unprotected onion plots<br>Protected onion plots | 3.87 ± 0.08a<br>0.42 ± 0.01b | F= 2241.58<br>P=0.0001 |
| | Bombay Red<br>BSS 230 Hybrid<br>Texas Grano<br>Red Comet<br>Red Creole | 2.58 ± 0.11a<br>2.77 ± 0.11a<br>1.80 ± 0.08c<br>1.33 ± 0.05d<br>2.23 ± 0.11c | F= 51.77<br>P= 0.0001 |
| b) Adults | Unprotected onion plots<br>Protected onion plots | 0.83 ± 0.01a<br>0.21 ± 0.01b | F= 2270.02<br>P= 0.0001 |
| | Bombay Red<br>BSS 230 Hybrid<br>Texas Grano<br>Red Comet<br>Red Creole | 0.61 ± 0.02a<br>0.57 ± 0.02a<br>0.45 ± 0.02b<br>0.40 ± 0.02b<br>0.57 ± 0.03a | F= 21.33<br>P= 0.0001 |
| c) Larvae + Adults | Unprotected onion plots<br>Protected onion plots | 4.70 ± 0.09a<br>0.63 ± 0.01b | F= 2484.79<br>P= 0.0001 |
| | Bombay Red<br>BSS 230 Hybrid<br>Texas Grano<br>Red Comet<br>Red Creole | 3.20 ± 0.12a<br>3.34 ± 0.12a<br>2.25 ± 0.09c<br>0.40 ± 0.02 d<br>2.80 ± 0.12b | F= 53.73<br>P= 0.0001 |

Means marked by the same letter(s) in the same column in a blocked row are not significantly different (P=0.05, SNK)

**Table 4.2:** Mean (± S.E) number of onion thrips per plant in the unprotected onion plots at KARI-Mwea and KARI-Thika during wet and dry seasons

| Site/Season | Variety | Larvae | Adults | Larvae+ Adults |
|---|---|---|---|---|
| KARI-Mwea / Wet Season | Bombay Red | 1.00 ± 0.06b | 0.20 ± 0.02ab | 1.20 ± 0.07b |
| | BSS 230 Hybrid | 1.33 ± 0.08a | 0.26 ± 0.03a | 1.60 ± 0.09a |
| | Texas Grano | 0.96 ± 0.06b | 0.20± 0.03ab | 1.16 ± 0.07b |
| | Red Comet | 0.83 ± 0.05b | 0.15± 0.02b | 0.98 ± 0.06b |
| | Red Creole | 0.90 ± 0.06b | 0.14± 0.02b | 1.04 ± 0.06b |
| KARI-Mwea / Dry Season | Bombay Red | 2.70 ± 0.18b | 0.65 ± 0.06b | 3.35 ± 0.21b |
| | BSS 230 Hybrid | 3.18 ± 0.28a | 0.70 ± 0.06b | 3.88 ± 0.32a |
| | Texas Grano | 1.62 ± 0.11d | 0.40 ± 0.04c | 2.02 ± 0.14c |
| | Red Comet | 2.19 ± 0.15c | 0.89 ± 0.06a | 3.08 ± 0.19b |
| | Red Creole | 2.55 ± 0.20bc | 0.70 ± 0.06b | 3.25 ± 0.24b |
| KARI-Thika / Wet Season | Bombay Red | 7.02 ± 0.64a | 0.94 ± 0.12a | 7.96 ± 0.69a |
| | BSS 230 Hybrid | 7.63 ± 0.59a | 0.75 ± 0.07ab | 8.38 ± 0.63a |
| | Texas Grano | 4.57 ± 0.47b | 0.57± 0.06b | 5.14 ± 0.50b |
| | Red Comet | 2.52 ± 0.28c | 0.25 ± 0.04c | 2.78 ± 0.31c |
| | Red Creole | 7.05 ± 0.70a | 0.97± 0.08a | 8.03± 0.76a |
| KARI-Thika / Wet Season | Bombay Red | 7.27 ± 0.36a | 1.90 ± 0.11a | 9.18 ± 0.04a |
| | BSS 230 Hybrid | 7.44 ± 0.39a | 1.85 ± 0.11ab | 9.29 ± 0.47a |
| | Texas Grano | 5.24 ± 0.28b | 1.52 ± 0.11b | 6.76 ± 0.35b |
| | Red Comet | 3.42 ± 0.20c | 1.08 ± 0.08c | 4.51 ± 0.24c |
| | Red Creole | 5.29 ± 0.31b | 1.75 ± 0.14ab | 7.05 ± 0.39b |

Means marked by the same letter(s) in the same column in a blocked row are not significantly different (P=0.05, SNK)

significant differences in the mean number of thrips infesting various onion varieties (F= 51.77, P=0.0001) A significantly higher numbers of larval thrips were recovered from Bombay Red and BSS 230 Hybrid onion varieties while Red Comet was significantly least attacked by larval thrips. Texas Grano and Red Creole significantly displayed a moderate level of attack by larval thrips.

Considering adult onion thrips, it was evident that there were significant differences between the protected and unprotected onion plots and also between varieties (F= 2270.02, P= 0.0001; F= 21.33, P= 0.0001 respectively). Significantly higher numbers of adult thrips infested the unprotected plots compared to the protected ones. The numbers of adult thrips infesting Bombay Red, BSS 230 Hybrid and Red Creole were significantly higher compared to those recovered from Texas Grano or Red Comet. Data analysis for the total onion thrips (larvae and adults) indicated that there were significant differences between the protected and unprotected onion plots and also between onion varieties (F= 2484.79, P= 0.0001; F= 53.73, P= 0.0001 respectively). There were significantly more numbers of onion thrips in the unprotected plots compared to the protected ones. Again, Bombay and BSS 230 Hybrid harboured the highest number of onion thrips followed by Red Creole, Texas Grano and Red Comet in that order.

Results of onion thrips population densities infesting various onion varieties obtained from the unprotected onion plots at individual trial sites are contained in table 4.2. Results revealed that at KARI-Mwea during the wet season (first season), there were significant differences in the numbers of larval, adult and total onion thrips (larvae and adults combined) (F= 11.10, P= 0.0001; F= 4.61, P= 0.0011, F= 13.69, P= 0.0001 in that order). BSS 230 hybrid had significantly the highest numbers of larval thrips compared to the rest of the varieties. On the other hand, Bombay Red, Texas Grano and Red Comet significantly recorded medium level of susceptibility while Red Creole had significantly the lowest level of infestation by larval thrips. Considering adult thrips abundance, the results indicated that BSS 230 Hybrid significantly harboured the highest number while Red Comet and Red Creole significantly harboured the lowest number of adult thrips. Bombay Red and Texas Grano recorded medium infestation levels by adult onion thrips. On the other hand, BSS 230 Hybrid significantly harboured the highest number of total thrips while Bombay Red, Texas Grano, Red Comet and Red Creole had lower population densties of onion thrips.

During the dry season (second season) at KARI-Mwea, results indicated that there were also significant differences in the number of larval, adult and total onion thrips between the tested onion varieties (F= 14.56, P= 0.0001; F=14.99, P= 0.0001; F= 15.35, P= 0.0001 in that order). BSS 230 Hybrid significantly harboured the highest number of larval thrips, followed by Bombay Red, Red Creole, Red Comet and Texas Grano in that order. The highest number of adult onion thrips was significantly attracted to Red Comet. Bombay Red, BSS 230 Hybrid, and Red Creole showed medium susceptibility to adult thrips infestation while Texas Grano significantly harboured the lowest numbers of adult onion thrips. During the same period, BSS 230 Hybrid significantly had the highest numbers of total onion thrips (larvae and adults) while Bombay Red, Red Comet and Red Creole displayed medium susceptibility levels. Texas Grano significantly had the lowest level of infestation by total onion thrips during the season.

Results of trials conducted at KARI-Thika are shown in table 4.2. Data analysis revealed that at KARI-Thika, during the wet season (first season) there were significant differences in the numbers of larval, adult and total onion thrips between onion varieties (F= 21.51, P= 0.0001; F=18.05, P= 0.0001; F= 23.74, P= 0.0001 in that order). The highest larval thrips density was significantly recorded for Bombay Red, BSS 230 Hybrid and Red Creole while Red Comet significantly harboured the lowest numbers. Texas Grano showed medium susceptibility level. The highest numbers of adult onion thrips were significantly attracted to Bombay Red and Red Creole while the lowest numbers were significantly recorded for Red Comet. BSS 230 Hybrid followed by Texas Grano significantly displayed medium susceptibility levels to attack by adult onion thrips during the season. The highest numbers of total onion thrips were significantly recorded for BSS 230 Hybrid, Bombay Red and Red Creole while the lowest was observed from Red Comet. Texas Grano displayed medium susceptibility to total onion thrips.

During the dry season (second season) at KARI-Thika site, there were also significant differences in the numbers of larval, adult and total onion thrips between onion varieties tested (F= 38.42, P= 0.0001; F=11.39, P= 0.0001; F= 37.24, P= 0.0001 in that order). Data analysis revealed that the highest numbers of larval onion thrips were significantly recorded for Bombay Red and BSS 230 Hybrid while the lowest numbers were significantly noted for Red Comet. Texas Grano and Red Creole significantly registered medium levels of attack by larval thrips. The highest numbers of adult onion thrips per plant at the site were significantly noted for Bombay Red while the lowest numbers were significantly recorded for Red Comet. BSS 230 Hybrid and Red Creole significantly registered the second highest numbers of adult onion thrips. Texas Grano was noted to significantly show the second lowest level of susceptibility to adult onion thrips at the site after Red Comet. Considering the total onion thrips (larvae and adults combined), it was evident that Bombay Red and BSS 230 Hybrid had significantly the highest levels of infestation and Red Comet had the lowest. Texas Grano and Red Creole showed medium susceptibility to attack by total onion thrips at the site during the season.

Laboratory identification of the species of thrips infesting onions indicated that at KARI-Thika site only onion thrips, *T. tabaci* were recovered from the samples. But at KARI-Mwea site, onions were infested by onion thrips, *T. tabaci* and western flower thrips, *F. occidentalis.* Commenting on the morphological features and relative maturity period of each onion variety, it was noted that Bombay Red produced red bulbs, was late maturing and had openly spaced leaves. BSS 230 Hybrid was observed to have a bushy growth habit with openly spaced leaves. It produced red skinned bulbs and was late maturing. Red Creole, another variety producing red skinned bulbs was noted to have openly spaced leaves and was also late maturing. On the other hand, Texas Grano and Red Comet were observed to mature early. Texas Grano had creamy white bulbs and leaves were openly attached to the plant. However, Red Comet was observed to have leaves with a closed architecture where the leaves at the growing points were compacted. The variety produced red bulbs.

### 4.3.2 Effects of Population Density of Onion Thrips on Damage to Onion Crop and Incidence of Onion Foliar Diseases

Detailed results of the effects of onion thrips on damage to onion leaves and incidence of onion foliar diseases are contained in tables 4.3 and 4.4. Results indicated that there were significant differences in the mean damage score between the protected and unprotected onion plots (F= 5644.16, P= 0.0001) and also the tested onion varieties (F= 45.77, P= 0.0001). The damage scores in the unprotected plots were found to be significantly higher than those of the protected plots. Considering onion varieties, Bombay Red and BSS 230 Hybrid significantly recorded the highest levels of onion pest damage while Red Creole significantly had the lowest damage score. Texas Grano and Red Comet significantly registered intermediate damage scores. There were no significant differences in damage scores between Bombay Red and BSS 230 Hybrid and the same applied to Texas Grano and Red Comet.

Results of the effects of onion thrips densities on damage of onion leaves recorded in the unprotected onion plots for KARI-Mwea and KARI-Thika sites during two cropping seasons are contained in table 4.4. Analysis of variance indicated that there were significant differences in onion foliar damage at KARI-

**Table 4.3:** The pooled mean (± S.E) of pest damage score by onion thrips and and frequency of occurrence of foliar onion diseases recorded during the trials.

| | Treatment | Mean number± S.E of onion thrips | |
|---|---|---|---|
| a) Pest damage score | Unprotected plots | 2.93 ± 0.01a | F= 5644.16 |
| | Protected plots | 2.34 ± 0.01b | P=0.0001 |
| | Bombay Red | 2.69 ± 0.02a | F= 45.77 |
| | BSS 230 Hybrid | 2.69 ± 0.02a | P= 0.0001 |
| | Texas Grano | 2.61 ± 0.02b | |
| | Red Comet | 2.63 ± 0.02b | |
| | Red Creole | 2.55 ± 0.02c | |
| b) Foliar Disease Incidence | KARI-Mwea Site | 5.08 ± 0.43a | F= 0.56 |
| | KARI-Thika Site | 5.28 ± 0.75a | P= 0.457 |
| | Wet season | 4.44 ± 0.53a | F= 7.22 |
| | Dry season | 5.81 ± 0.67a | P= 0.0078 |
| | Bombay Red | 4.50 ± 0.98a | F= 1.13 |
| | BSS 230 Hybrid | 6.62 ± 1.07a | P= 0.2660 |
| | Texas Grano | 4.33 ± 0.84a | |
| | Red Comet | 5.35 ± 1.01a | |
| | Red Creole | 5.10 ± 1.01a | |

Means marked by the same letter(s) in the same column in a blocked row are not significantly different (P=0.05, SNK)

The occurrence of foliar onion diseases was evaluated from the differences recorded from the protected and unprotected onion plots

**Table 4.4:** Mean (± S.E) damage score and frequency of foliar onion diseases in the unprotected plots at KARI-Mwea and KARI-Thika during wet and dry seasons

| Site/Season | Variety | Damage score | Foliar disease incidence |
|---|---|---|---|
| KARI-Mwea / Wet Season | Bombay Red | 2.76± 0.02c | 15.15 ± 1.15a |
| | BSS 230 Hybrid | 2.78± 0.03c | 14.10 ± 3.90a |
| | Texas Grano | 2.86± 0.02b | 17.15 ± 1.35a |
| | Red Comet | 2.97± 0.02a | 16.45 ± 2.15a |
| | Red Creole | 2.57± 0.03d | 15.50 ± 3.10a |
| KARI-Mwea / Dry Season | Bombay Red | 2.26± 0.04b | 22.62 ± 0.54a |
| | BSS 230 Hybrid | 2.39± 0.04a | 24.66 ± 1.42a |
| | Texas Grano | 2.20± 0.04c | 26.69 ± 1.31a |
| | Red Comet | 2.32± 0.04b | 24.00 ± 0.00a |
| | Red Creole | 2.28± 0.04b | 19.04 ± 0.42b |
| KARI-Thika / Wet Season | Bombay Red | 3.47± 0.06a | 23.88 ± 1.04a |
| | BSS 230 Hybrid | 3.47± 0.06a | 22.29 ± 0.71a |
| | Texas Grano | 3.14± 0.05b | 22.21 ± 0.29a |
| | Red Comet | 3.16± 0.06b | 21.46 ± 0.38a |
| | Red Creole | 3.18± 0.06b | 20.38 ± 0.80a |
| KARI-Thika / Dry Season | Bombay Red | 3.41± 0.05a | 33.54 ± 2.54a |
| | BSS 230 Hybrid | 3.43± 0.05a | 32.96 ± 2.46a |
| | Texas Grano | 3.39± 0.05a | 34.58 ± 1.92a |
| | Red Comet | 3.20± 0.05c | 32.42 ± 3.84a |
| | Red Creole | 3.27± 0.05b | 31.42 ± 2.75a |

Means marked by the same letter(s) in the same column in a blocked row are not significantly different (P=0.05, SNK)

Mwea between onion varieties during the first and second cropping seasons (F= 40.87, P= 0.0001; F= 11.42, P= 0.0001 for the first and second seasons respectively). During the first season at KARI-Mwea, Red Comet significantly recorded the highest damage score followed by Texas Grano, BSS 230 hybrid and Bombay Red. There were no significant differences in damage score between Bombay Red and BSS 230 Hybrid. The lowest damage score was significantly observed for Red Creole during the season. During the second season in the unprotected onion plots at KARI-Mwea, results revealed that the highest damage score was significantly recorded for BSS 230 Hydrid and the lowest for Texas Grano. There were no significant differences in damage score between Red Comet, Red Creole and Bombay Red during the season.

Considering results from KARI-Thika in the unprotected onion plots, it was evident that there were significant differences in damage scores between the onion varieties in the first and second seasons (F= 54.91, P= 0.0001; F= 18.68, P= 0.0001 for the first and second seasons respectively). During the first season at the site, Bombay Red and BSS 230 Hybrid significantly registered the highest pest damage score although there were no significant differences between them. Red Creole, Red Comet and Texas Grano significantly had the lowest damage score although there were no significant differences between them. During the second season at the site, the highest damage scores were significantly observed for BSS 230 Hybrid, Bombay Red and Texas Grano but there were no significant differences between them. The second lowest damage score was significantly noted for Red Creole while Red Comet significantly registered the lowest damage score at the site during the season.

The effects of infestation by onion thrips on occurrence of foliar diseases affecting various onion varieties are contained in tables 4.3 and 4.4. Analysis of variance of the pooled data indicated that there were no significant differences in occurrence of foliar diseases between the two experimental sites, seasons and onion varieties (F= 0.56, P= 0.4569; F= 7.22, P= 0.0078; F= 1.31, P= 0.2660 in that order). However, the mean frequencies of foliar disease incidences were higher for KARI-Thika site compared to KARI-Mwea site. There were also more incidences of foliar diseases during the second season compared to the first season.

Results of incidence of foliar onion diseases in the unprotected onion plots during the wet and dry seasons at the individual experimental sites are contained in table 4.4. There were no significant differences in the mean frequencies of foliar disease incidence between the onion varieties at KARI-Mwea during the first cropping season (F= 0.13, P= 0.9715). The frequencies of foliar disease incidence on onion varieties in order of decreasing importance were as follows: Texas Grano, Red Comet, Red Creole, Bombay Red and BSS 230 Hybrid. However, during the second season at KARI-Mwea, there were significant differences in the occurrence of foliar onion diseases between onion varieties (F= 1.86, P= 0.01217). Red Creole significantly registered the lowest incidence of foliar onion diseases. There were no significant differences in foliar disease incidence between Bombay Red, BSS 230 Hybrid, Texas Grano and Red Comet during the cropping season at the site. The frequencies of disease incidence observed on various onion varieties during the second season at the site in order of decreasing importance were as follows: Texas

Grano, BSS 230 Hybrid, Bombay Red, Red Comet and Red Creole. Results from KARI-Thika indicated that there were no significant differences in the mean frequencies of foliar disease incidence between the varieties during the first and second seasons (F= 0.13, P= 0.9702; F= 0.31, P= 0.8698 respectively). During the first season, frequencies of disease incidence in various onion varieties in order of decreasing importance were Bombay Red, BSS 230 Hybrid, Texas Grano, Red Comet and Red Creole. During the second season the order was Texas Grano, Bombay Red, BSS 230 Hybrid, Red Comet and Red Creole. It was generally observed that there were more incidences of foliar diseases during the second season compared to the first season at the two sites. It was also noted that the occurrence of onion foliar diseases was higher at KARI-Thika than at KARI-Mwea site during the two cropping seasons.

### 4.3.3 Effects of Stage of Growth of Onion Crop and Weather Variables on Population Density of Onion Thrips

The effects of stage of growth of onion crop and weather variables (temperature and rainfall) on population trends of onion thrips are contained in figures 4.1, 4.2, 4.3 and 4.4. Results obtained from KARI-Mwea during the first cropping season indicated that there was an increase in the number of onion thrips from 27- 34 Days after Transplanting (DAT) for all the onion varieties tested. The number of thrips recorded during this period was generally high compared to the rest of the season.

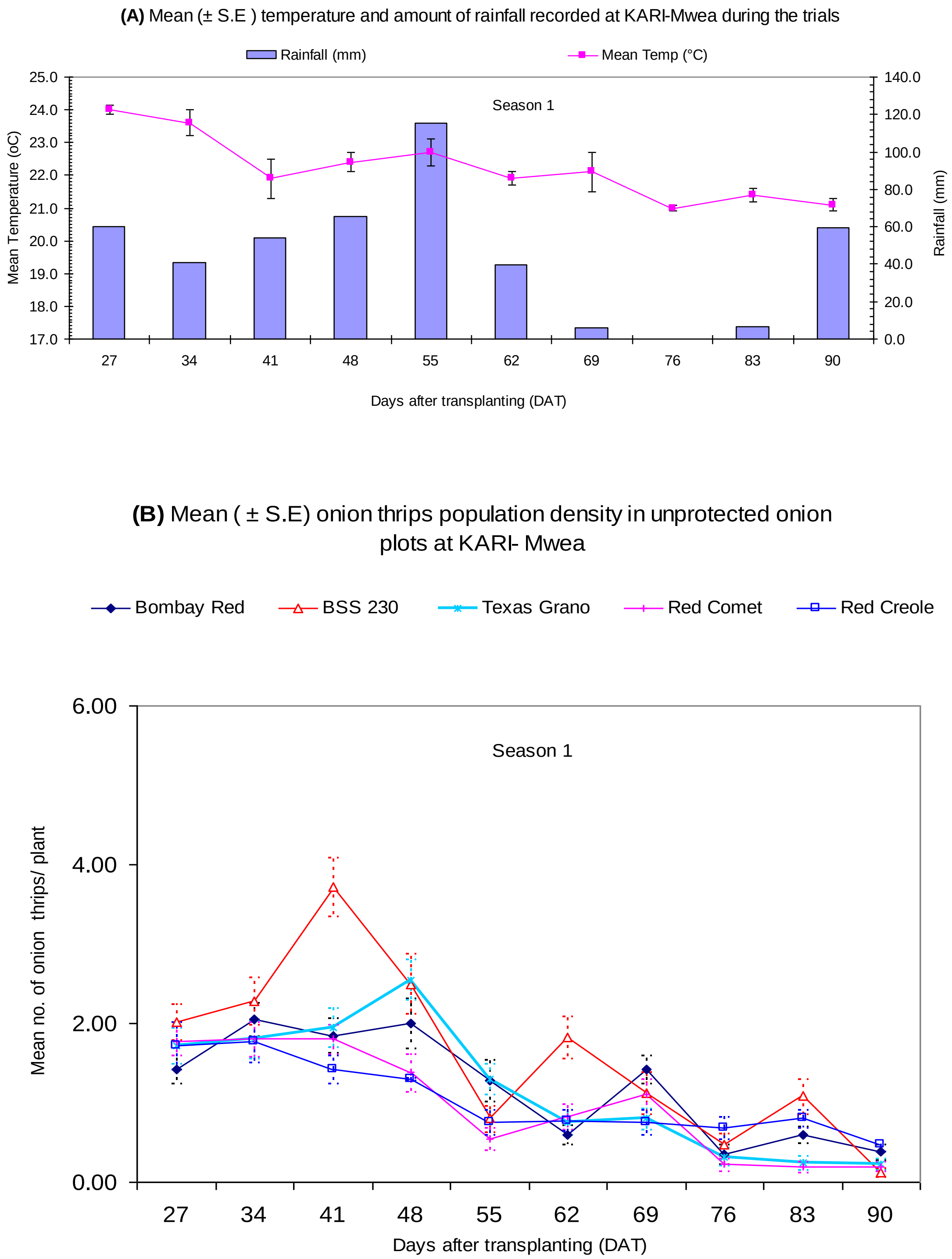
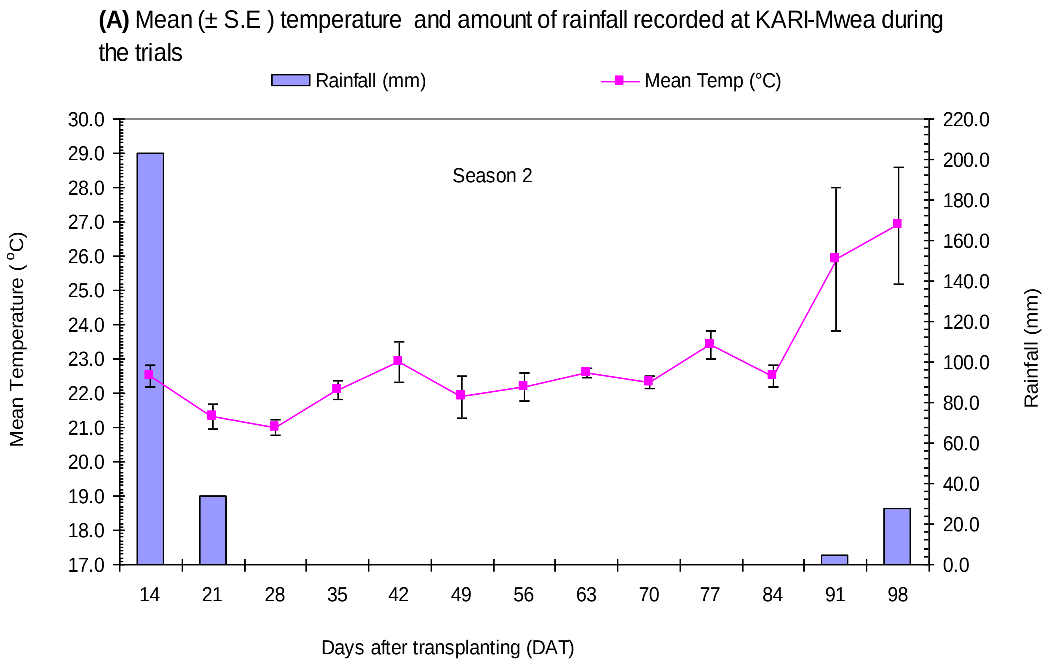



**Fig 4.1:** Relationship between onion thrips population trends and the corresponding mean (± S.E) temperature and rainfall recorded at KARI-Mwea trial site during the first season



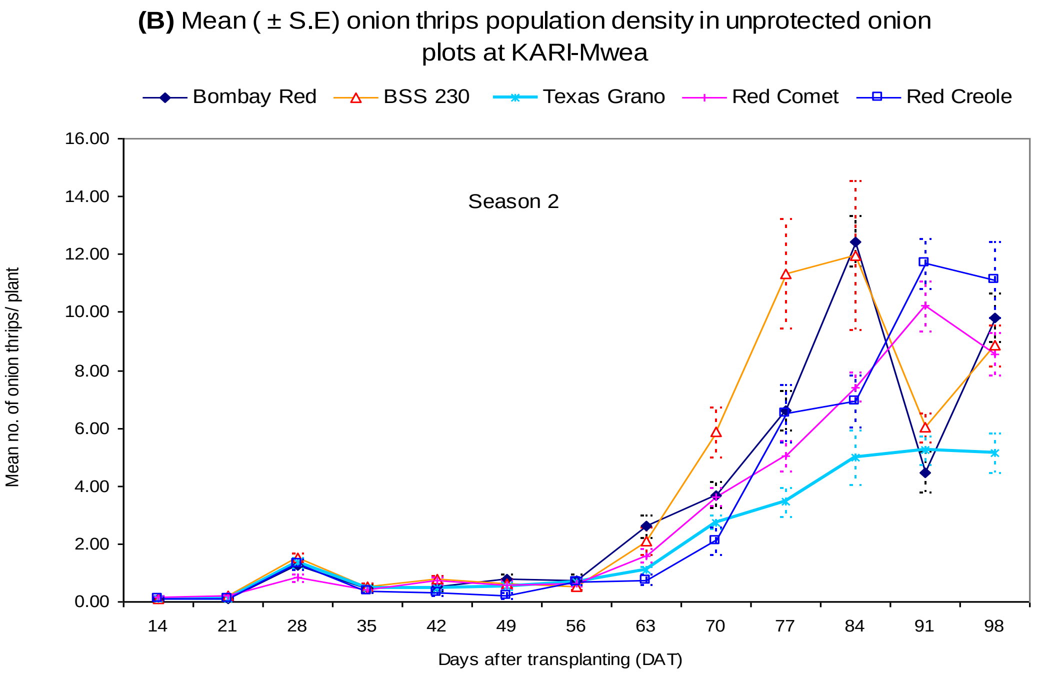




**Fig 4.2:** Relationship between onion thrips population trends and the corresponding mean (± S.E) temperature and rainfall recorded at KARI-Mwea trial site during the second season

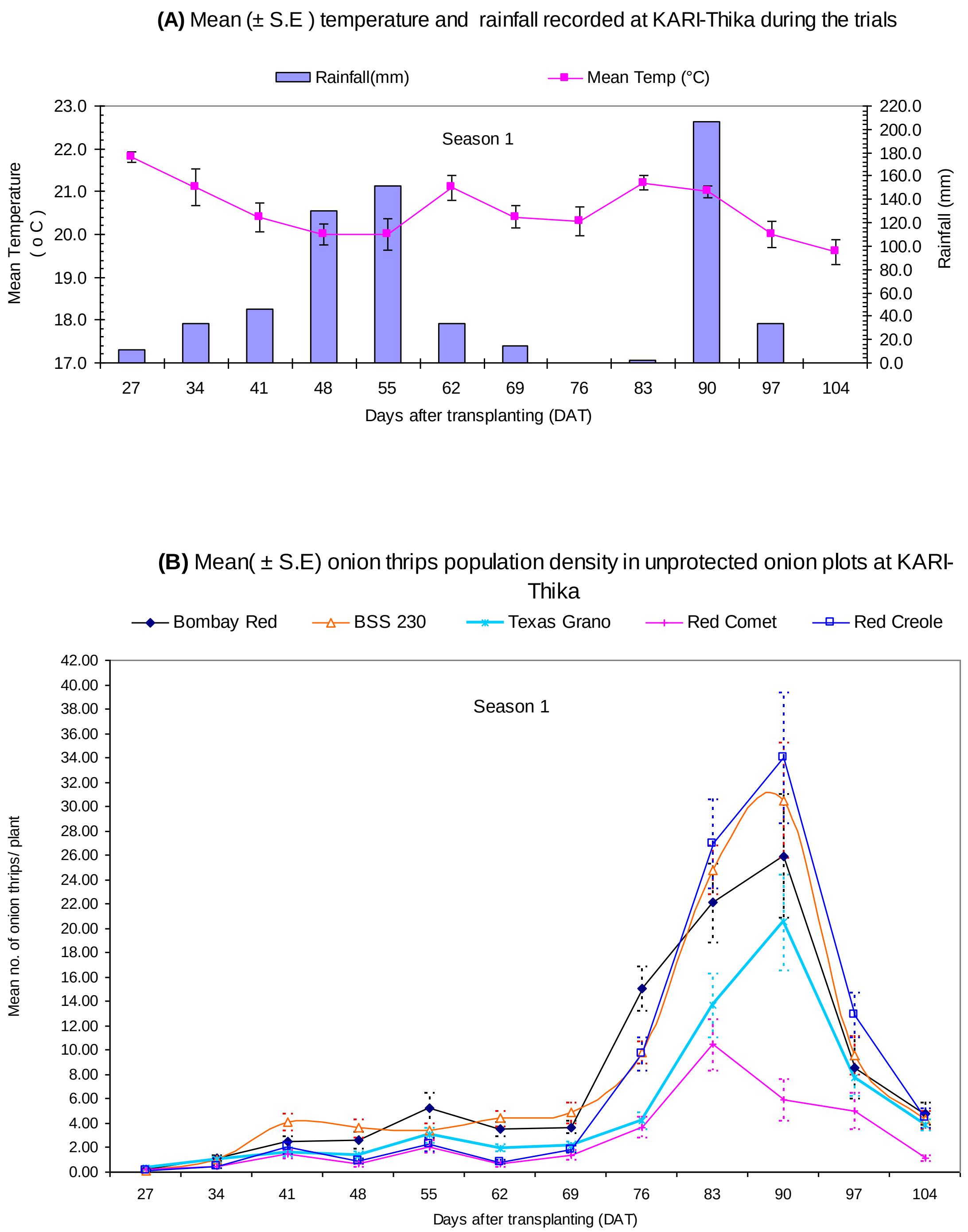



**Fig 4.3:** Relationship between onion thrips population trends and the corresponding mean (± S.E) temperature and rainfall recorded at KARI-Thika trial site during the first season

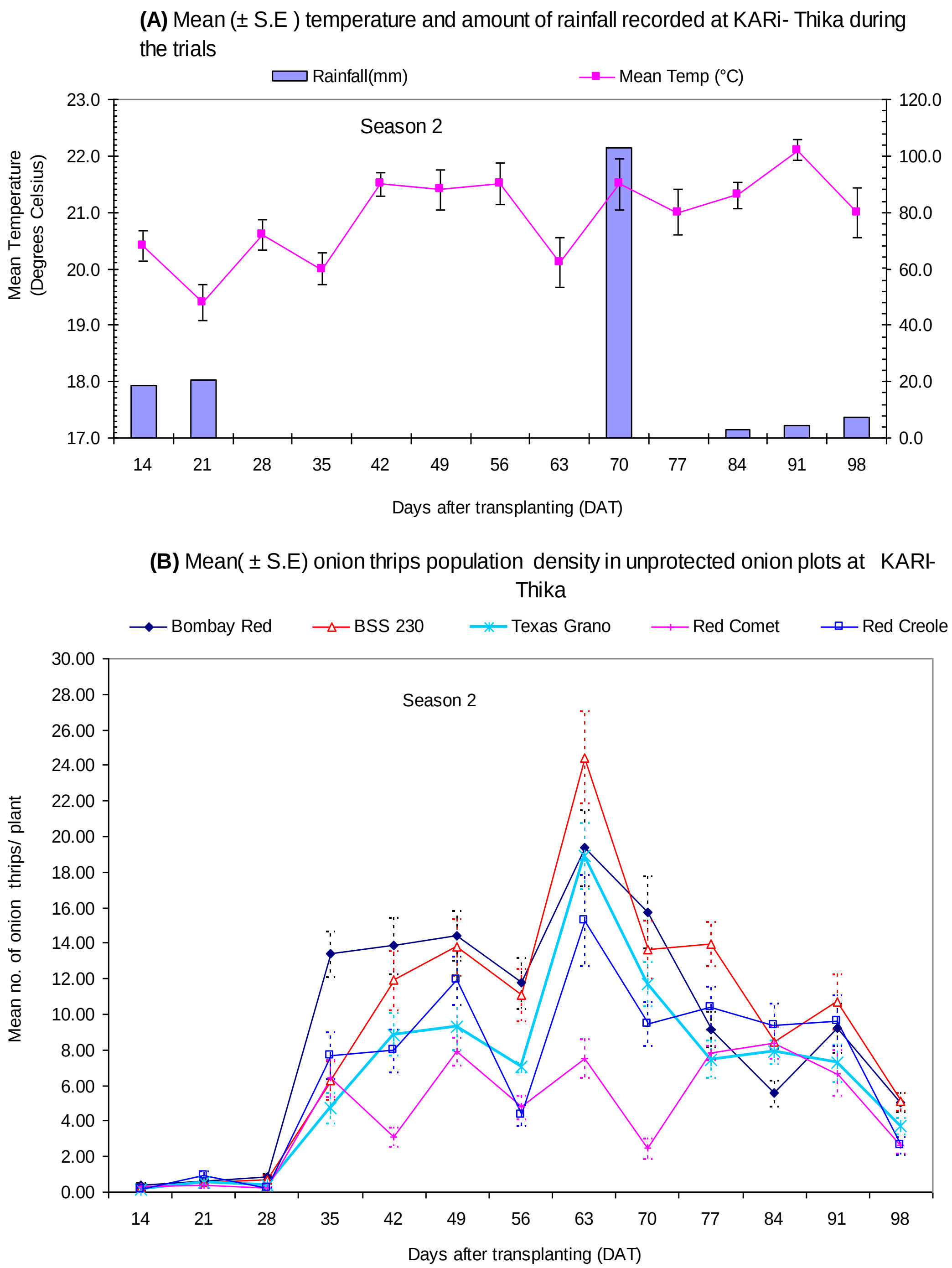



**Fig 4.4:** Relationship between onion thrips population trends and the corresponding mean (± S.E) temperature and rainfall recorded at KARI-Thika trial site during the second season

The temperatures recorded during the period were relatively high compared to the remaining part of the cropping season. Except for BSS 230 Hybrid and slightly for Texas Grano, all other onion varieties registered a decline in the numbers of onion thrips from 34-55 DAT. This period was characterized by high rainfall and more or less constant temperatures. The decline in numbers of onion thrips reached the trough (lowest level) at 55 DAT, a period that was marked by peak rainfall. The numbers of thrips fluctuated slightly from 55-90 DAT for all the varieties, a period that was also marked by decline in rainfall and more or less constant temperatures. Except for BSS 230 Hybrid, the number of thrips peaked at 48, 69 and 83 DAT for all other varieties. The peaks for BSS 230 Hybrid were noted to generally occur one week earlier than for the rest of the varieties.

During the second season at KARI-Mwea, there were very few onion thrips between 14 DAT and 21 DAT for all the varieties tested. The period was characterized by heavy downpour and declining temperatures. There was slight increase in the number of thrips from 21-28 DAT; a period that was also marked by decline in rainfall. The number of onion thrips remained low and more or less constant for all the varieties between 28 DAT and 63 DAT, a period which had slight fluctuations in temperatures but no rainfall. There was a sharp increase in numbers of onion thrips at the site between 63 DAT and 84 DAT when the numbers of onion thrips recorded for Bombay Red and Texas Grano reached the peak. The peaks for Red Comet and Red Creole were reached one week later. There was a gradual increase in temperature between 84 DAT and 98 DAT. Decrease in the number of onion thrips was also found to occur from 84- 91 DAT for BSS 230 Hybrid and Bombay Red and later (91- 98 DAT) for Red Comet and Red Creole. This period was marked by the onset of long rains.

Considering results from KARI-Thika during the first season, it was evident that the numbers of thrips were lower for all the varieties between 27 DAT and 69 DAT, a period marked by some rainfall and declining temperatures. Steady increase in the number of thrips was observed for all the varieties between 69 DAT and 90 DAT except for Red Comet which had reached the peak one week earlier. From 90-104 DAT, there was a sharp decline in the number of onion thrips for all the varieties tested. This period was also marked by peak rainfall and declining temperatures that reached the lowest levels at 104 DAT. Bombay Red and BSS 230 Hybrid had the highest number of thrips at 90 DAT.

During the second season at KARI-Thika, it was observed that the number of onion thrips remained low from 14-28 DAT for all the varieties, a duration that was also characterized by low rainfall and temperatures. There was a steady increase in the number of onion thrips from 56-63 DAT for all the varieties before again dropping up to 84 DAT. The exception was for BSS 230 Hybrid. The period was marked by peak rainfall and slightly fluctuating temperatures. The number of thrips slightly increased between 84-91 DAT for BSS 230 Hybrid, Bombay Red and Red Creole before decreasing between 91-98 DAT for all the onion varieties. This period experienced decreasing temperatures and low rainfall. During the early stages of crop growth (0-30 DAT ) there were generally low levels of infestation of onion thrips on various onion varieties but the numbers gradually increased to peak at bulb enlargement stage (60-90 DAT) before declining towards crop maturation stage ( 90-120 DAT), a period marked by widespread senescence of onion leaves.

## 4.4 DISCUSSION

The present study revealed that onion thrips, *Thrips tabaci* Lindeman was a major pest of onions in Kenya. This finding was consistent with work reported by Waiganjo (2004). Apart from onion thrips, western flower thrips, *Frankliniella occidentalis* Pergande were recovered from onion plots at KARI-Mwea in Kirinyaga District, again confirming the findings reported in an earlier study by Waiganjo (2004). The presence of western flower thrips in onion fields was most likely due to migrations from surrounding French bean fields, a proposition held by Waiganjo (2004). French beans was the second most important income generating enterprise in Mwea as reported earlier in chapter three of this report and was cited as a major host of western flower thrips by Gitonga *et al.* (2002). Western flower thrips were not recovered at KARI-Thika most likely because bean production was a less important enterprise in the area. Effective use of insecticides to control thrips in onion fields in the study area was likely to be much more complicated by the presence of western flower thrips since the pest was reported to easily develop resistance to pesticides (Immaraju *et al.*, 1992; Gitonga, 1999; Waiganjo, 2004). The reason why this pest developed resistance very easily has remained a matter of conjecture and there was a needto do more studies in this area.

It was established from the present study that there were significantly more larval, adult and total onion thrips population densities in the unprotected onion plots compared to the protected ones. This meant that the insecticides used in the protected plots were of high efficacy since they were able to greatly reduce populations of onion thrips in the protected plots. However, the few thrips recorded from the protected plots could have been as a result of resurgence of pest populations after decimination of the natural enemies and development of insect-resistant populations, as was reported by Boyhan *et al*. (2002). It was also possible that the residual effects of the pesticides used were not long lasting. Although pesticides were considered as the most potent means of suppressing pests, their use should be kept to a minimum because of development of insecticide resistance, incompatibility with biological control agents and the risks of chemical residues on fresh vegetables, among other reasons (Sithanantham, *et al.,* 2004). Moreover, it was reported by Lewis (1997) that there was no universally ideal thripsicide and over all loomed the apparently inexorable development of resistance with the consecquent need to devise and employ resistant-retarding strategies.

Data analysis indicated that different onion varieties available in Kenya had different levels of susceptibility to onion thrips. In particular, it was established that BSS 230 Hybrid and Bombay Red onion varieties were highly susceptible to infestations by onion thrips. On the contrary, Red Comet was the least susceptible as it harboured the lowest number of onion thrips. The levels of susceptibility of Red Creole and Texas Grano were shown to be moderate. Generally, Bombay Red was generall shown to be more attractive to adult onion thrips compared to other onion varieties. There was a need to study the cues followed by adult thrips to identify Bombay Red as a preferred host plant. The low number of adult thrips compared to the larval forms recovered from all the onion varieties was most likely due to their high mobility. The attractiveness of BSS 230 Hybrid and Bombay Red to attack by onion thrips was most likely due to their bushy growth habits, among other factors. These varieties formed many openly spaced leaves which tended to provide better hiding places for onion thrips. The high susceptibility of the two onion cultivars might also be associated with their late maturity where they remained attractive to the pests for a longer period especially during the most vulnerable onion growth stages. Red Creole, a popular, red cultivar with a pungent strong smell and widely grown in Kenya was used as a local check in the trials. The variety displayed a moderate level of susceptibility, contrary to an earlier held view reported by Waiganjo (2004). The second lowest level of susceptibility to onion thrips was recorded for Texas Grano, a variety characterized by creamy white bulbs, less pungency and early maturity. This finding was consistent with the findings reported in other parts of the world by other scientists as outlined below. Boica *et al* (1987) reported that Texas Grano was less susceptible to thrips and Pawar *et al.* (1987) concluded that white onions were less susceptible to attack by onion thrips compared to red onions. The chemicals that were inherent in these white varieties that act as deterrents to attack by onion thrips were not well documented and required further investigations. Apart from bulb colour, Texas Grano was also found to be early maturing thus escaping the peak when the pest would have build up to economic injury levels. Red Comet was observed to have the least level of susceptibility to attack by onion thrips. The mechanism for this host plant resistance was most likely attributed to the morphological features of the cultivar where the onion leaves at growing points were firmly compacted thus denying onion thrips their preferred hinding places to protect against adverse weather conditions and their natural enemies. This conclusion was supported by the findings reported by Fournier *et al.* (1995). The variety was also early maturing enabling the crop to escape heavy onion thrips infestations due to migrations from surrounding areas.

The seasonal and regional differences in the average number of thrips recorded during the trials could have been as a result of different weather conditions particularly temperature and rainfall experienced at the two trial sites. The mean temperatures recorded at KARI-Mwea were slightly higher during the second season (22.78 ± 0.28 °C) compared to the first season (22.57 ± 0.17 °C). The total rainfall received during the second season at KARI-Mwea was lower (317.8 mm) compared to the amount received during the first season (398.7 mm). The same trend was observed for KARI-Thika. The mean temperature and total rainfall recorded during the first and second seasons at the site were 20.68 ± 0.10 °C and 669.5 mm and 20.91 ± 0.10 °C and 360.0 mm respectively. High temperatures and low rainfall were seen to favour high population densities of onion thrips while high rainfall and low temperatures tended to reduce the level of infestation on various onion varieties. These conclusions seemed to be in agreement with the findings reported by Lorini and Junior (1990) who concluded that high temperature and lack of rainfall increased the population densities of thrips since high temperatures favoured rapid multiplication of onion thrips and heavy rainfall washed off the thrips from plants. The reasons why there were more thrips at KARI-Thika than at KARI-Mwea despite of the relatively low temperatures and high rainfall at KARI-Thika were not very clear and required further investigation.

The present study revealed that the extent to which onion leaves were damaged by onion thrips depended on their numbers on the crop. In the protected plots, the damage of onion leaves by onion thrips was found to be significantly lower than in the unprotected ones. This implied that the pesticides used in the protected plots were of high efficacy since they were able to check the population of onion thrips on the crop. This was in agreement with the findings reported by Muriuki (1982) and Waiganjo (2004) who concluded that several insecticides were effective in the control of onion thrips in Kenya.  In onion farms, pesticides should form part of the integrated pest management strategy for the control of onion thrips where they were combined with other options such as host plant resistance and cultural practices.

It was observed in the present study that there existed significant differences in damage of onion leaves by thrips between onion varieties. The highest damage levels recorded for BSS 230 Hybrid and Bombay Red were best accounted for by the higher number of onion thrips recovered from the varieties. The bushy growth habits of these varieties might have been advantageous to onion thrips by providing better hiding places as reported by Fournier *et al.* (1995). The damage of onion leaves of

Texas Grano and Red Comet were found to be significantly lower than what was recorded for BSS 230 Hybrid and Bombay Red. This was supported by the low number of onion thrips recovered from the varieties, besides the low number of leaves produced by the varieties which provided less protection to the thrips against adverse weather conditions and natural enemies. The lowest level of damage of onion leaves by thrips was noted for Red Creole. The reasons for this observation were not well understood and required further investigation. However, it was possible that the popularity of Red Creole among many onion farmers in Kenya was associated with this observation. Comparing the observations obtained from individual experimental sites, it was found that damage of onion leaves by onion thrips was higher for KARI-Thika than KARI-Mwea. The high score was noted to correspond to the high number of onion thrips recorded from the site. The low number of onion thrips and the resultant low foliar damage observed at KARI-Mwea implied that the area had comparative advantage over KARI-Thika area in the production of onions, a conclusion that was also advanced by Kimani and Mbatia (1993). The damage of onion leaves was found to be higher during the dry season compared to the wet season. Low rainfall and high temperatures tended to promote the number of onion thrips infesting various onion varieties which resulted in high damage score.

The present research revealed that there were no significant differences in the occurrence of foliar diseases associated with attack by thrips among the onion varieties. However, it was generally noted that the incidence of foliar diseases was higher at KARI-Thika than KARI-Mwea which corresponded with the high number of thrips recorded for the site. Again, there were more incidences of fungal onion diseases during the dry season compared to the wet season. A higher concentration of onion thrips on various onion varieties was noted to occur during the dry season. Considering onion varieties, BSS 230 Hybrid and Bombay Red were found to have higher incidences of foliar onion diseases compared to other varieties. Texas Grano was found to be the most susceptibe to onion diseases although it had the second lowest number of thrips attracted to it. The reasons for the high susceptibility to diseases were not very clear and required further investigation. Red Creole was found to be the least susceptible to onion fungal diseases, a characteristic which could have contributed to its popularity in Kenya. High number of thrips generally tended to be associated with higher incidences of onion foliar diseases, a finding that was also reported by Waiganjo (2004). This was because feeding injuries by thrips predisposed the plant tissues to subsequent invasion by bacterial and fungal pathogens as reported by Lewis (1997).

The present investigation revealed that generally, the lowest number of onion thrips for all the varieties included in the study occurred during the early stages of crop growth (0-30 days after transplanting). As the crop matured, the number of onion thrips steadily increased to peak during 60-90 days after transplanting and therafter the numbers went down. However, there was an exception at KARI-Mwea during the first cropping season, where the numbers of onion thrips were generally found to be high during the first 40 days after transplanting, most likely due to the effects of high temperatures recorded at the time. For the rest of the experiment period at the site, the number of thrips generally went down up to crop maturation stage which occurred four months after transplanting. The former observations implied that bulb enlargement onion growth stage (3 months after transplanting) was the most critical when control tactics for onion thrips should be concentrated. These findings were in agreement with results of earlier experiment conducted in Kenya, where it was reported by Waiganjo (2004) that the highest number of onion thrips occurred during the bulbing and bulb enlargement stages while the lowest numbers were observed during the pre-bulbing and bulb maturation growth stages. According to the author, during the pre-bulbing stage the crop had ability to have compensatory growth while during bulb maturation the leaves underwent senescence thus making the plants less attractive to thrips.

According to the findings of the present study, dry seasons characterized by high temperatures and low amount of rainfall triggered an increase in number of thrips on onion plants. Wet seasons marked by high rainfall and cool temperatures had the converse effect. The fluctuations in number of thrips observed during various stages of onion crop growth were associated with sudden changes in weather variables, particularly rainfall and temperatures, besides other factors. It was observed that incidental downpour resulted in a decrease in the number of onion thrips, most likely due to them being washed off the plants. The findings on the effect of temperature and rainfall were in agreement with the conclusions made by

Harris *et al* (1936), Harding (1963), Lorini and Junior (1990 and Doimiciano *et al.* (1995) and van Rijn *et al.* (1995).

In conclusion, it was evident from the present study that various onion varieties grown in Kenya have varying levels of susceptibility to attack by onion thrips and therefore plant-host resistance could be considered as an important component of integrated pest management against onion thrips in Kenya. Results indicated that large number of onion thrips were associated with high levels of damage of onion leaves and also predisposed onions to disease pathogens. Further bulb enlargement stage was noted to be the most susceptible and critical onion growth stage when onion thrips control should be concentrated. Finally, it was apparent that there was a positive relationship between the number of onion thrips infesting various onion varieties and temperature and a negative relationship with rainfall.

# CHAPTER 5

## 5.0 EFFECTS OF POPULATION DENSITY OF ONION THRIPS ON CROP GROWTH, YIELD AND BULB QUALITY

### 5.1 INTRODUCTION

Onion crop is attacked by both larval and adult thrips at all stages of growth resulting in reduction in onion quality and yield (Waiganjo *et al.*, 2008). The most serious effect of thrips infestation is the resultant reduction in bulb yield (Coviello and McGiffen, 1995). Yield losses ranging between 18% and 60% caused by population thresholds of 19.6- 62.0 thrips per plant have been reported in Kenya (Waiganjo, 2004). Onion thrips population densities of 17.9 thrips per plant and below were found not to affect onion yield (Waiganjo, 2004). Records from many parts of the world indicate heavy losses because of T. *tabaci* infestation in onions. For example, in Portugal, Boica *et al.* (1987) showed that onion thrips were responsible for yield loss of 62%. In Quebec (Canada), heavy infestation by onion thrips resulted in losses of 43% and 34.5% in 1988 and 1989 respectively (Fournier *et al.,* 1995). Research by Sanderson (1995) demonstrated that thrips feeding had the potential to significantly reduce onion yields. The reduction was in form of smaller onion bulbs that resulted from the feeding activity after bulbing. Yield reduction due to reduced bulb size is the primary crop loss caused by onion thrips and increased plant maturity and senescence due to thrips injury may truncate the bulb growth period (Alston and Drost, 2008).

The aim of the present study was to evaluate the effects of the population densities of onion thrips on onion crop growth, yield and bulb quality. The findings of these studies are presented in this chapter.

## 5.2 MATERIALS AND METHODS

### 5.2.1 Experimental Design and Treatments

The experimental design ant treatments were as described in chapter two, sub-sections 2.2.2 and 2.2.3.

### 5.2.2 Effects of Population Densities of Onion Thrips on Onion Crop Growth

The growth of onion plants was monitored starting from the third week and second week after transplanting for the the first and second season crops respectively. Thereafter, sampling was done after every two weeks until the crop exhibited signs of harvest maturity. The parameters determined included the number of leaves and the fresh weight (fresh biomass) of each sampled plant. Five onion plants selected randomly from the rows that were used for sampling of thrips were uprooted and taken to the laboratory for the assessments. The samples were put in polythene bags, sealed to minimize loss of moisture and kept in a cool place. They were also carefully handled to ensure that leaves remained intact before they were weighed and counted. Assessments of the variables were carried out as soon as the samples reached the laboratory. In the laboratory, the number of leaves and fresh weight of each sampled plant were determined and recorded. Weighing was done using a digital balance for accuracy. The reductions in crop growth due to attack by onion thrips were evaluated using the formulae:

i) Reduction in number of leaves = number of leaves in protected plot - number of leaves in unprotected plot.

ii) Reduction in fresh weight = weight from protected plot – weight from unprotected plot.

### 5.2.3 Yield Capacities of Onion Varieties Grown in Kenya

Investigations on yield capacities of various onion varieties in protected and unprotected onion plots were carried out at the two trial sites for two cropping seasons. Onion bulbs were harvested when about 20-50% of the pseudo-stems of onion plants had lodged. Three middle rows of each plot were harvested for yields determination, leaving 30 cm from each edge of the rows. The maximum effective area harvested was 2.16 $m^2$. The stems and roots of each harvested plant were trimmed off. Bulbs were then air-dried for three days before weighing them. The average weight of harvested bulbs per plot was determined using a digital balance and the yield extrapolated to metric tonnes per hectare. Yield of onion bulbs per hectare and percent reductions in yield due to attack by onion thrips for each onion variety were calculated using the formulae:

i) $$\text{Bulb yield (t/ha)} = \frac{\text{Total weight of bulbs per plot (Kg)}}{\text{Effective harvested area (m}^2\text{)}} \times 10$$

ii) % reduction in yield = $\frac{\text{Yield of protected plot} - \text{Yield of unprotected plot}}{\text{Yield of protected plot}} \times 100$

### 5.2.4 Effects of Infestation of Onion Thrips on Quality of Onion Bulbs

The effects infestation of onion thrips on quality of onion bulbs obtained from various onion varieties were evaluated in terms of mean bulb diameter, bulb weight and mean reductions in onion grades 1, 2 and 3. The diameters of onion bulbs were determined using a vernier caliper. Grading of onion bulbs was done as suggested by Nguthi *et al*. (1994). All harvested bulbs were counted and sorted into grade 1 (≥ 5 cm bulb diameter), grade 2 (< 5 cm but > 3 cm bulb diameter) and grade 3 (≤ 3 cm bulb diameter). The average weight of bulbs per plot was determined. The reduction in onion grade was evaluated using the formula:

- Reduction in grade of onions = weight of the grade in protected plot – weight of the grade in unprotected plot.

### 5.2.5 Data Analysis

Data was analysed using Statistical Analysis System program (SAS, 8.1; SAS Institute, 2000). Data on bulb yield, percent reduction in yield, number of leaves, fresh weight, bulb diameter, bulb weight and reductions in various onion grades were subjected to analysis of variance (ANOVA). Means of the above variables were separated using Student- Newman- Keuls multiple range test. The probability level of significance of P= 0.05 was used unless otherwise stated.

## 5.3 RESULTS

### 5.3.1 Effects of infestations of Onion thrips on Growth of Onion Crop

Results of the effects of infestations of onion thrips on growth of onion crop are contained in tables 5.1 and 5.2. Results indicated that there were no sibnificant differences in the mean reductions in the number of leaves and fresh weight due to infestations by onion thrips between the onion varieties (F= 1.68, P= 0.1531; F= 0.46, P= 0.7659 for the number of leaves and fresh weight respectively). However, a close examination indicated that highest reductions in number of leaves were recorded for Bombay Red followed by BSS 230 Hybrid, Red Creole, Red Comet and Texas Grano in that order. Generally the onion varieties that showed reductions in fresh weight in order of decreasing importance included Red Comet, Bombay Red, BSS 230 Hybrid, Red Creole and Texas Grano.

Information on the number of leaves and fresh weight recorded from the unprotected onion plots at KARI-Mwea and KARI-Thika sites are contained in table 5.2. Results indicated that at KARI-Mwea, there were significant differences in the number of leaves and fresh weights between onion varieties during the first cropping season (F= 54.14, P= 0.0001; F= 21.78, P= 0.0001 for leaves and fresh weight respectively). During the first season at the site, BSS 230 Hybrid significantly

**Table 5.1:** The pooled mean (± S.E) reductions in number of leaves and fresh weight (gm) recorded during the trials

| | Treatment | Mean reductions in leaves/ fresh weight | |
|---|---|---|---|
| a) Leaves | | | |
| | Bombay Red | 0.53 ± 0.13a | F= 1.68 |
| | BSS 230 Hybrid | 0.35 ± 0.12a | P= 0.1531 |
| | Texas Grano | 0.06 ± 0.11a | |
| | Red Comet | 0.21 ± 0.09a | |
| | Red Creole | 0.26 ± 0.13a | |
| b) Fresh weight | | | |
| | Bombay Red | 7.28 ± 2.23a | F= 0.46 |
| | BSS 230 Hybrid | 6.84 ± 2.06a | P= 0.7659 |
| | Texas Grano | 3.83 ± 2.81a | |
| | Red Comet | 8.35 ± 2.28a | |
| | Red Creole | 5.50 ± 2.17a | |

Means marked by the same letter(s) in the same column in a blocked row are not significantly different (P=0.05, SNK)

**Table 5.2:** Mean (± S.E) number of leaves and fresh weight in the unprotected plots at KARI-Mwea and KARI-Thika during wet and dry seasons

| Site/Season | Variety | Number of leaves | Fresh weight |
|---|---|---|---|
| KARI-Mwea / Wet Season | Bombay Red | 8.05 ± 0.23b | 92.15 ± 6.5b |
| | BSS 230 Hybrid | 8.97 ± 0.25a | 105.60 ± 7.21b |
| | Texas Grano | 7.38 ± 0.25c | 128.02 ± 9.90a |
| | Red Comet | 5.32 ± 0.23d | 72.27 ± 5.13c |
| | Red Creole | 8.46 ± 0.22ab | 95.07 ± 6.55b |
| KARI-Mwea / Dry Season | Bombay Red | 8.48 ± 0.49a | 67.33 ± 7.82a |
| | BSS 230 Hybrid | 7.74 ± 0.33b | 63.18 ± 6.61a |
| | Texas Grano | 6.14 ± 0.23d | 70.22 ± 8.36a |
| | Red Comet | 4.62 ± 0.19e | 28.13 ± 3.99b |
| | Red Creole | 7.00 ± 0.35c | 63.00 ± 7.64a |
| KARI-Thika / Wet Season | Bombay Red | 7.32 ± 0.28ab | 56.43 ± 4.48bc |
| | BSS 230 Hybrid | 7.60 ± 0.24a | 64.87 ± 4.66b |
| | Texas Grano | 6.83 ± 0.25b | 78.78 ± 6.55a |
| | Red Comet | 5.62 ± 0.19c | 53.08 ± 0.45c |
| | Red Creole | 7.27 ± 0.28ab | 58.29 ± 4.59bc |
| KARI-Thika / Dry Season | Bombay Red | 5.31 ± 0.14a | 18.00 ± 1.53b |
| | BSS 230 Hybrid | 5.08 ± 0.14a | 13.81 ± 1.12c |
| | Texas Grano | 5.20 ± 0.14a | 22.77 ± 2.41a |
| | Red Comet | 3.71 ± 0.10b | 7.27 ± 0.73d |
| | Red Creole | 5.12 ± 0.18a | 14.64 ± 1.60c |

Means marked by the same letter(s) in the same column in a blocked row are not significantly different (P=0.05, SNK)

produced the highest number of leaves followed by Red Creole, Bombay Red and Texas Grano in that order. Red Comet significantly produced the lowest number of leaves. During the same time at the site, Texas Grano significantly recorded the highest fresh weight while Red Comet registered the lowest. There were no significant differences in fresh weights between BSS 230 Hybrid, Red Creole and Bombay Red. During the second season at KARI-Mwea in the unprotected plots, results indicated that there were significant differences in the number of leaves and fresh weight between onion varieties (F= 49.63, P= 0.0001; F= 18.28, P= 0.0001 for leaves and fresh weight respectively). During the season, Bombay Red and Red Comet significantly produced the highest and the lowest number of leaves respectively. The second highest numbers of leaves were significantly produced by BSS 230 Hybrid followed by Red Creole and Texas Grano. During the period, Texas Grano, Bombay Red, BSS 230 Hybrid and Red Creole significantly registered the highest fresh weights while Red Comet significantly registered the lowest weight.

Results from KARI-Thika trial site indicated that there were significant differences in the number of leaves and fresh weights between the onion varieties during the first cropping season (F= 17.42, P= 0.0001; F= 10.25, P= 0.0001 for leaves and fresh weight respectively). During the season BSS 230 Hybrid significantly recorded the highest number of leaves followed by Bombay Red and Red Creole. The second lowest number of leaves was significantly noted for Texas Grano while the lowest was significantly observed from Red Comet. The fresh weights recorded at the site were significantly higher for Texas Grano followed by

BSS 230 Hybrid. Red Creole and Bombay Red significantly registered the third highest weight while Red Comet significantly registered the lowest fresh weight. During the second season at the KARI-Thika site in the unprotected plots, results revealed that there were significant differences in the number of leaves and fresh weights between the onion varieties (F= 24.40, P= 0.0001; F= 22.62, P= 0.0001 for leaves and fresh weight respectively). Bombay Red, Texas Grano and Red Creole significantly produced the highest numbers of leaves while Red Comet significantly produced the lowest. The second highest number of leaves was significantly recorded by BSS 230 Hybrid. Considering fresh weights, Texas Grano, significantly recorded the highest fresh weight, followed by Bombay Red. Red Creole and BSS 230 Hybrid significantly registered the second lowest fresh weight. Red Comet significantly had the lowest fresh weight during the season at the site.

### 5.3.2 Yield capacities and the Effects of Infestations of onion Thrips on Bulb Yield of Onion Varieties Grown in Kenya

The results of onion yields and yield reductions associated with infestations of onion varieties by onion thrips at KARI-Mwea and KARI-Thika sites are shown in tables 5.3 and 5.4. It was clear that there were variations in yield between sites, seasons and varieties. Considering the results obtained from the protected plots at KARI-Mwea, it was shown that yields ranged from 27.8-55.5 t/ha and 39.5-71.6 t/ha in the first and the second cropping seasons respectively. Higher yields were obtained during the second season compared to the first season for all the varieties

**Table 5.3:** Mean (± S.E) onion yields (t/ha) of varieties grown in protected and unprotected plots at KARI-Mwea and KARI-Thika sites.

| Variety | Mwea/ Rainy season | Mwea/ Dry season | Thika/ Rainy season | Thika/ Dry season |
|---|---|---|---|---|
| **a) Protected Plots** | | | | |
| Bombay Red | 27.80 ± 2.12c | 50.50 ± 2.30b | 26.32 ± 2.99a | 14.50 ± 1.76ab |
| BSS 230 | | | | |
| Hybrid | 35.08 ± 2.07bc | 55.60 ± 3.99b | 30.55 ± 2.24a | 20.60 ± 1.02ab |
| Texas Grano | 55.50 ± 3.42a | 71.62 ± 3.63a | 39.25 ± 7.80a | 22.60 ± 3.50a |
| Red Comet | 40.65 ± 3.83b | 39.52 ± 1.77c | 27.28 ± 4.25a | 11.60 ± 2.35b |
| Red Creole | 37.28 ± 2.80b | 48.52 ± 1.01b | 27.02 ± 2.69a | 15.10 ± 2.56ab |
| **b) Unprotected Plots** | | | | |
| Bombay Red | 26.45 ± 2.88b | 45.40 ± 1.58b | 16.75 ± 2.58bc | 9.05 ± 1.11b |
| BSS 230 | | | | |
| Hybrid | 29.78 ± 2.05b | 43.10 ± 2.35b | 20.60 ± 2.56b | 7.38 ± 1.02b |
| Texas Grano | 47.70 ± 4.49a | 67.88 ± 3.54a | 31.82 ± 3.85a | 14.75 ± 1.99a |
| Red Comet | 30.38 ± 5.78b | 36.18 ± 2.42b | 12.98 ± 2.14c | 3.32 ± 0.46c |
| Red Creole | 31.60 ± 2.70b | 41.48 ± 2.54b | 20.00 ± 1.81b | 7.72 ± 0.64b |

Means marked by the same letter(s) in the same column in a blocked row are not significantly different (P=0.05, SNK)

**Table 5.4:** Mean (± S.E) reductions in bulb yield (%) of onion varieties grown at KARI-Mwea and KARI- Thika sites

| Variety | Mwea/ Rainy season | Mwea/ Dry season | Mwea/ Rainy season | Mwea/ Dry season |
|---|---|---|---|---|
| Bombay Red | 3.84 ± 10.41a | 9.74 ± 4.04a | 36.71 ± 4.68ab | 33.64 ± 12.37a |
| BSS 230 Hybrid | 13.45 ± 10.38a | 21.86 ± 4.13a | 32.64 ± 5.80ab | 64.56 ± 3.45a |
| Texas Grano | 14.54 ± 3.05a | 5.12 ± 2.79a | 15.72 ± 6.46b | 34.17 ± 2.68a |
| Red Comet | 26.09 ± 9.50a | 8.31 ± 6.02a | 51.71 ± 4.44a | 66.32 ± 9.41a |
| Red Creole | 15.22 ± 4.03a | 14.66 ± 3.50a | 25.43 ± 4.02b | 41.33 ± 14.72a |

Means marked by the same letter(s) in the same column in a blocked row are not significantly different (P=0.05, SNK)

tested at the site. There were significant differences in yields between various onion varieties during the first and second cropping seasons at the site (F=17.78, P= 0.0001; F= 19.06, P= 0.0001 for the first and second seasons respectively). During the first season, Texas Grano significantly produced the highest yield while Bombay Red significantly had the lowest yield. The second highest yield was significantly obtained from BSS 230 Hybrid. There were no significant significant differences in bulb yields between Red Comet and Red Creole during the season. During the second season at the site in the protected plots, Texas Grano once again significantly produced the highest yield while Red Comet significantly had the lowest yield. There were no significant differences in yields between BSS 230 Hybrid, Bombay Red and Red Creole during the season

Results obtained from KARI-Thika in the protected plots, indicated that yields ranged from 26.3-39.2 t/ha and 11.6-22.6 t/ha in the first and second seasons respectively. During the first season at the site results indicated that there were no significant differences in yields between onion varieties (F= 3.54, P= 0.0483). However, Texas Grano gave the highest yield followed by BSS 230 Hybrid, Red Comet, Red Creole and Bombay Red in that order. During the second season at the site, results indicated that there were significany differences in yields between the onion varieties (F= 2.19, P= 0.1426). During the period, Texas Grano significantly produced the highest yield while Red Comet significantly had the lowest yield. There were no significant differences in yields between BSS 230 Hybrid, Bombay Red and Red Creole.

Comparing yields obtained in the unprotected plots at KARI- Mwea and KARI-Thika sites, it was evident that yields were higher at Mwea than at Thika. It was also shown that higher yields were obtained during the first season compared to the second season. Results obtained from KARI-Mwea site in the unprotected plots indicated that there were significant differences in yields between the various onion varieties during the first and second cropping seasons. (F= 12.71, P= 0.0003; F= 19.10, P= 0.0001 for first and second seasons respectively). During the first season at the site, yields ranged from 26.4-30.4 t/ha for the varieties tested. Texas Grano significantly produced the highest yield. There were no significant differences in yields between the rests of the varieties. However, Red Creole produced the second highest yield followed by Red Comet, BSS 230 Hybrid and Bombay Red in that order. During the second season at KARI-Mwea site yields ranged from 36.2-67.9 t/ha for the varieties tested. Texas Grano significantly produced the highest yield. Yields from the rest of onion varieties were not significantly different although Bombay Red produced the second highest yield followed by BSS 230 Hybrid, Red Creole and Red Comet in that order.

Considering results obtained from KARI-Thika in the unprotected onion plots, yields ranged from 13.0- 31.8 t/ha and 3.3- 14.8 t/ha in the first and second seasons respectively for the varieties tested. There were significant differences in yields between onion varieties during the first and second cropping seasons (F= 15.39, P= 0.0001 and F= 24.35, P= 0.0001 for the first and second seasons respectively). During the first season at the site, Texas Grano significantly produced the highest yield while Red Comet significantly produced the lowest yield. The second highest yield was significantly produced by Bombay Red, followed by BSS 230 Hybrid and Red Creole respectively. But there were no significant differences in yields between BSS 230 Hybrid and Red Creole. During the second season at the site, Texas Grano significantly produced the highest yield while Red Comet significantly had the the lowest yield. The second highest yields were got from Bombay Red and this was followed by Red Creole and BSS 230 Hybrid. There were no significant differences in yields between Bombay Red, Red Creole and BSS 230 Hybrid.

Results on percent reductions in yields associated with infestations of onion varieties by onion thrips are contained in Table 5.4. Analysis of variance indicated that there were no significant differences in percent yield reductions between various onion varieties during the first and second seasons at Mwea ($F= 1.17$, $P= 0.3604$; $F= 1.21$, $P= 0.3472$ for the first and second seasons respectively). There were significant differences in yield reductions between onion varieties at KARI-Thika during the first season ($F= 1.22$, $P= 0.0459$) but during the second season there were no significant differences ($F= 2.17$, $P= 0.1447$). Generally, during the first season at KARI-Mwea, the percent reductions in yield due to attack of onion varieties by thrips were higher for Red Comet compared to the rest of the varieties. The percent reductions recorded for the onion varieties in order of decreasing importance were Red Comet, Red Creole, Texas Grano, BSS 230 Hybrid and Bombay Red. During the second season at the site, the reductions in yield in order of decreasing importance included BSS 230 Hybrid, Red Creole, Bombay Red, Red Comet and Texas Grano.

At KARI-Thika during the first cropping season, there were significant differences in percent yield reductions between the varieties. The highest reduction was significantly recorded for Red Comet, followed by Bombay Red and BSS 230 Hybrid. The lowest reductions were significantly registered by Texas Grano and Red Creole. During the second season at the site, there were no significant differences in percent reductions in yield between onion varieties. However, Red Comet had the highest loss of yield, followed by BSS 230 Hybrid, Red Creole, Texas Grano and Bombay Red in that order.

### 5.3.3 Effects of Infestations of Onion Thrips on Quality of Onion Yield

Results of the capacities of various onion varieties to produce onions of high quality are shown in tables 5.5 and 5.6. Results indicated that at KARI-Mwea in the protected plots there were significant differences in the diameters of onion bulbs between various onion varieties during the first and second cropping seasons ($F= 15.65$, $P= 0.0001$; $F= 29.75$, $P= 0.0001$ for first and second seasons respectively). During the first season at the site, Texas Grano significantly produced bulbs with largest diameter while the lowest were significantly produced by Red Comet. The second largest bulbs were significantly produced by BSS 230 Hybrid and were followed by those of Bombay Red and Red Creole respectively. During the second season at the site, Texas Grano significantly produced bulbs with the largest diameter

**Table 5.5:** Mean (± S.E) bulb diameter (cm) recorded in protected and unprotected plots at KARI-Mwea and KARI-Thika sites during two cropping seasons

| Variety | Mwea/ Rainy season | Mwea/ Dry season | Thika/ Rainy season | Thika/ Dry season |
|---|---|---|---|---|
| **a) Protected Plots** | | | | |
| Bombay Red | 6.32 ± 0.18b | 5.92 ± 0.14a | 4.98 ± 0.13a | 2.80 ± 0.17a |
| BSS 230 Hybrid | 6.55 ± 0.05ab | 5.88 ± 0.11a | 5.50 ± 0.12a | 3.30 ± 0.11a |
| Texas Grano | 6.98 ± 0.17a | 5.95 ± 0.13a | 5.52 ± 0.34a | 3.18 ± 0.29a |
| Red Comet | 5.35 ± 0.21c | 4.20 ± 0.20c | 4.30 ± 0.17b | 1.92 ± 0.24b |
| Red Creole | 6.25 ± 0.25b | 5.22 ± 0.15b | 5.08 ± 0.23a | 2.55 ± 0.31a |
| **b) Unprotected Plots** | | | | |
| Bombay Red | 5.95 ± 0.18b | 5.52 ± 0.12a | 4.42 ± 0.26a | 2.05 ± 0.13b |
| BSS 230 Hybrid | 5.92 ± 0.17b | 5.40 ± 0.13a | 4.60 ± 0.28a | 1.80 ± 0.20b |
| Texas Grano | 6.70 ± 0.22a | 5.72 ± 0.11a | 5.00 ± 0.19a | 2.50 ± 0.23a |
| Red Comet | 4.68 ± 0.20c | 3.85 ± 0.25c | 3.28 ± 0.19b | 0.70 ± 0.11c |
| Red Creole | 5.72 ± 0.21b | 4.80 ± 0.12b | 4.38 ± 0.16a | 1.72 ± 0.10b |

Means marked by the same letter(s) in the same column in a blocked row are not significantly different (P=0.05, SNK)

**Table 5.6:** Mean (± S.E) bulb weight (gm) recorded in protected and unprotected plots at KARI-Mwea and KARI-Thika sites during two cropping seasons

| Variety | Mwea/ Rainy season | Mwea/ Dry season | Thika/ Rainy season | Thika/ Dry season |
|---|---|---|---|---|
| **a) Protected** | | | | |
| Bombay Red | 86.8 ± 3.98c | 151.50 ± 6.84bc | 71.82 ± 4.95a | 43.60 ± 5.35ab |
| BSS 230 Hybrid | 105.22 ± 6.27bc | 166.85 ± 12.02b | 91.62 ± 6.68a | 61.78 ± 3.07ab |
| Texas Grano | 172.00 ± 7.26a | 214.88 ± 10.96a | 117.78 ± 23.41a | 66.85 ± 10.35a |
| Red Comet | 121.88 ± 11.48b | 121.02 ± 4.98c | 81.85 ± 12.72a | 34.80 ± 7.05b |
| Red Creole | 111.80 ± 8.36b | 145.55 ± 3.00bc | 81.00 ± 8.03a | 45.25 ± 7.67ab |
| **b) Unprotected** | | | | |
| Bombay Red | 76.38 ± 6.21b | 136.25 ± 4.65b | 50.28 ± 7.75bc | 27.10 ± 3.35b |
| BSS 230 Hybrid | 86.05 ± 2.47b | 129.35 ± 7.03b | 61.78 ± 7.70b | 22.05 ± 3.06b |
| Texas Grano | 143.08 ± 13.43a | 203.52 ± 10.59a | 94.02 ± 11.49a | 44.12 ± 5.97a |
| Red Comet | 91.15 ± 17.31b | 108.48 ± 7.27b | 37.45 ± 6.90c | 10.00 ± 1.43c |
| Red Creole | 94.80 ± 8.06b | 123.40 ± 6.64b | 59.98 ± 5.43b | 23.18 ± 1.96b |

Means marked by the same letter(s) in the same column in a blocked row are not significantly different (P=0.05, SNK)

while the lowest were significantly produced by Red Comet. There were no significant differences in bulb diameters between Bombay Red, BSS 230 hybrid and Red Creole during the period.

Results from KARI-Thika in the protected plots indicated that there were significant differences in bulb diameter between various onion varieties during the first and second cropping seasons (F= 8.39, P= 0.0018; F= 7.61, P= 0.0027 for the first and second seasons respectively). During the first season at the site, Texas Grano, BSS 230 Hybrid, Red Creole and Bombay Red significantly produced bulbs with the largest diameter although there were no significant differences between them. Red Comet significantly produced the smallest bulbs during the period. The same trend was observed during the second season at the site.

Considering results obtained at KARI-Mwea in the unprotected plots, it was evident that there were significant differences in bulb diameters between various onion varieties during the first and second cropping seasons (F= 16.74, P= 0.0001; F= 28.83, P= 0.0001 for the first and second seasons respectively). During the first season at the site, Texas Grano, Bombay Red and BSS 230 Hybrid significantly produced the largest bulbs although there were no significant differences between them. The smallest bulbs were significantly produced by Red Comet while Red Creole produced medium sized bulbs. During the second season at the site, the same trend was observed.

Results from KARI-Thika in the unprotected plots indicated that there were significant differences in bulb diameters between various onion varieties during the first and second cropping seasons (F= 12.27, P= 0.0003; F= 35.40, P= 0.0001 for the first and second seasons respectively). During the first season at the site, Texas Grano, BSS 230 Hybrid, Bombay Red and Red Creole significantly produced the largest sized bulbs although there were no significant differences between them. Red Comet significantly produced the smallest bulbs during the season. Considering the second season, it was observed that Texas Grano significantly had the largest bulbs. The second largest bulbs were significantly produced by Bombay Red, BSS 230 Hybrid and Red Creole although there were no significant differences between them. Red Comet significantly produced the smallest bulbs during the season. It was generally observed that large sized bulbs were produced in the protected plots compared to the unprotected ones at the two trial sites during the two cropping seasons. Large sized bulbs were produced more common at Mwea than Thika. It was also observed that large sized bulbs were more common during the first season compared to the second season at the two trial sites.

Results of the bulb weight recorded at KARI-Mwea and KARI-Thika sites during two cropping seasons are contained in table 5.6. At KARI-Mwea in the protected plots, results indicated that there were significant differences in bulb weights between onion varieties during the first and the second growing seasons (F= 24.47, P= 0.0001; F= 17.59, P= 0.0001 for the first and second seasons respectively). During the first season at the site, Texas Grano significantly produced the heaviest bulbs followed by BSS 230 Hybrid. Red Comet and Red Creole produced bulbs of medium weight while Bombay Red significantly produced the lighest bulbs. During the second season at the site, Texas Grano significantly produced the heaviest bulbs followed by BSS 230 Hybrid. Bombay Red and Red Creole significantly produced bulbs of medium weight. Red Comet significantly produced the lightest bulbs.

Considering results from KARI-Thika in the protected plots, it was noted that there were no significant differences in bulb weights between onion varieties during the first season (F= 2.78, P= 0.0762) but the converse was true during the second season (F= 4.24, P= 0.0229). During the first season at the site, Texas Grano produced the heaviest bulbs followed by BSS 230 Hybrid, Red Comet, Red Creole and Bombay Red in that order although there were no significant differences between them. During the second season at the site, Texas Grano significantly produced the heaviest bulbs. Bulbs of medium weight were produced by BSS 230 Hybrid, Red Creole and Bombay Red although there were no significant differences between them. The lighest bulbs were significantly produced by Red Comet.

Results from KARI-Mwea in the unprotected onion plots, indicated that there were significant differences in bulb weights between various onion varieties during the first and second cropping seasons (F= 10.85, P= 0.0006; F= 20.19, P= 0.0001 for the first and second seasons respectively). During the first season at the site, Texas Grano significantly produced the heaviest bulbs compared to the rest of the varieties. There were no significant differences in bulb weight between Red Creole, Red Comet, BSS 230 Hybrid and Bombay Red. The same tend was observed during the second season at the site.

Considering results from KARI-Thika in the unprotected plots, it was noted that there were significant differences in bulb weights between various onion varieties during the first and second cropping seasons (F= 15.47, P= 0.0001; F= 20.10, P= 0.0001 for the first and second seasons respectively). During the first season at the site, Texas Grano significantly produced the heaviest bulbs followed by Bombay Red. Bulbs of medium weight were produced by BSS 230 Hybrid and Red Comet. The lighest bulbs were significantly produced by Red Comet. During the second season at tha site, Texas Grano significantly produced the heaviest bulbs while the lighest bulbs were significantly produced by Red Comet. Bombay Red, Red Creole and BSS 230 Hybrid produced bulbs of medium weight although there were no significant differences between them.

It was generally observed that onion bulbs obtained from KARI-Mwea were heavier than those from KARI-Thika. Heavier bulbs were produced in the protected plots compared to the unprotected ones at the two sites. At KARI-Mwea, heavier bulbs were produced during the second season compared to the first season. On the contrary, heavier bulbs were produced during the first season at KARI-Thika compared to those recorded at KARI-Mwea.

Results on reductions in grades of onions recorded at KARI-Mwea and KARI-Thika sites during the trials are indicated in table 5.7. The losses in various onion market grades due to infestations of onion thrips were evaluated in the present study as a measure of onion bulb quality. Results indicated that there was no significant reduction in grade one (jumbo or colossal grade) between sites, seasons and varieties

**Table 5.7:** The pooled mean (± S.E) reductions in onion grades (Kg) due to infestation by onion thrips recorded at KARI-Mwea and KARI-Thika trial sites

| Onion Grades | Treatment | Mean (± S.E) reduction in grade (Kg) | |
|---|---|---|---|
| Grade1 | Mwea | 1.15 ± 0.20a | F=0.24 |
| | Thika | 1.01 ± 0.26a | P=0.6255 |
| Grade 2 | Mwea | - 0.18 ± 0.08b | F= 18.36 |
| | Thika | 0.63 ± 0.22a | P=0.0001 |
| Grade 3 | Mwea | -0.05 ± 0.02a | F=0.02 |
| | Thika | -0.04 ± 0.07a | P=0.8775 |
| Grade1 | Season 1 | 1.20 ± 0.23a | F= 0.67 |
| | Season 2 | 0.97 ± 0.16a | P=0.4160 |
| Grade 2 | Season 1 | -0.18 ± 0.10a | F=18.75 |
| | Season 2 | 0.64 ± 0.14a | P=0.0001 |
| Grade 3 | Season 1 | -0.04 ± 0.15a | F= 0.02 |
| | Season 2 | -0.05 ± 0.14a | P=0.8859 |
| Grade 1 | Bombay Red | 0.93 ± 0.30a | F= 0.60 |
| | BSS 230 Hybrid | 1.51 ± 0.34a | P=0.6635 |
| | Texas Grano | 0.94 ± 0.35a | |
| | Red Comet | 0.95 ± 0.33a | |
| | Red Creole | 1.08 ± 0.27a | |
| Grade 2 | Bombay Red | 0.08 ± 0.18a | F=0.39 |
| | BSS 230 Hybrid | 0.41 ± 0.41a | P=0.8148 |
| | Texas Grano | 0.30 ± 0.20a | |
| | Red Comet | 0.12 ± 0.21a | |
| | Red Creole | 0.23 ± 0.22a | |
| Grade 3 | Bombay Red | -0.05 ± 0.05a | F= 2.26 |
| | BSS 230 Hybrid | -0.13 ± 0.08a | P=0.0710 |
| | Texas Grano | -0.13 ± 0.07a | |
| | Red Comet | 0.15 ± 0.17a | |
| | Red Creole | -0.09 ± 0.04a | |

Means marked by the same letter(s) in the same column in a blocked row are not significantly different (P=0.05, SNK). Minus means a gain in onion grade

(F=0.24, p= 0.6255; F= 0.67, p = 0.4160; F= 0.60, p= 0.6035 in that order). Considering reduction in grade two (medium grade), results indicated that there was significant difference between the sites and seasons but not between the varieties (F= 18.36, p= 0.0001; F= 18.75, p= 0.0001; F= 0.39, p= 0.8148 in that order). The highest reductions in grade two were significantly experienced at KARI-Thika site. There were also significantly more reductions during the first season compared to the second season. Results indicated that there were gains in onion grade three (small or inferior quality) due to onion thrips which were not significant between the sites, season and onion varieties (F= 0.02, p= 0.8775; F= 0.02, p= 0.8857; F= 2.26, p= 0.0710 in that order).

## 5.4 DISCUSSION

It was established from the present study that infestations by a large number of onion thrips adversely affected the growth of onion crop. Although there were no significant differences in the overall reductions in number of leaves and fresh weight due to attack by thrips observed between the varieties, close observations from individual trial sites suggested otherwise. The high reductions in these parameters of growth observed for Bombay Red and BSS 23 hybrid onion varieties were related to the heavy infestations recorded from the varieties. Red Creole was noted to show medium susceptibility to attack by thrips since it registered mediun reductions in leaves and fresh weight. On the other hand, Texas Grano which was noted to be second least attractive to infestations by onion thrips displayed the least susceptibility in terms of losses of growth. Red Comet which was found to harbour the least number of thrips recorded the highest losses of growth implying that it was least tolerant to injuries by onion thrips. It was also observed that the number of leaves and fresh biomass recored by the varieties tested were higher during the wet season which was marked by low number of thrips. During the dry season, the converse was also true. This finding implied that heavy infestations by onion thrips led to losses in the growth of onion crop. The regional differences in the number of thrips observed between KARI-Mwea and KARI-Thika were also suggestive as to the role played by thrips in growth of onion crop. Higher growth losses were noted for KARI-Thika which was also marked by heavy infestations by onion thrips compared to KARI-Mwea site. The losses in onion growth were associated with the damages caused by onion thrips to the onion leaves which led to reduced photosynthetic ability and nutrient availability to plants as was reported by Coviello and McGiffen (1995). The reductions in the number of leaves could be attributed to greater ethylene production in onions damaged by thrips which enhanced foliage scenescence as was reported by Kendall and Bjostad (1990).

It was established fron the present study that there was a direct relationship between the number of leaves produced by a particular onion variety and the number of thrips recovered from them. It was evident that BSS 230 Hybrid and Bombay Red produced more leaves while Texas Grano and Red Comet produced less leaves. The varieties producing more leaves also harboured more onion thrips. The converse was also true. The bushy growth habit of some of the onion varieties provided better hinding places for onion thrips against adverse weather conditions and natural enemies as was suggested by Coudriet *et al*. (1979) and Fournier *et el.* (1995). It was established from the present study that there was a direct relationship between the fresh weight and the bulb yield. The varieties that recorded high fresh weight also produced high bulb yield. It implied that fresh weight determination during the growth of onion crop could be used by farmers to generally evaluate the yield potential of various onion varieties.

The present study revealed that yield capacities of onion varieties grown in Kenya were dependent on many factors including the agroecological zone, the crop pest burden and the season. The results indicated that all the varieties had a higher yield potential at Mwea agroecological zone than at Thika zone. This meant, therefore, that onions performed well in Mwea than in Thika. This finding seemed to support the reason why Mwea was selected in the campaign for enhanced commercial production of bulb onions in 1950s as reported by Kimani and Mbatia (1993).

It was evident from the results of this investigation that majority of onion varieties available in Kenya had the potential of yielding more than 30 tonnes/ha in situations where all recommended agronomic practices were observed and in environments where thrips burdens were low. The observed high yield capacities were far above the world average of 17.7 t/ha as reported by FAO (2000) and Msuya *et al*. (2001). These yields were comparable to the high yields realized in countries like China, Spain and Japan as documented by Kimani and Mbatia (1993), Nguthi *et* *al*. (1994) and FAO (1999). However, in an agroecological area where thrip burdens were high, yields fell drastically to as far as 3.3 t/ha as was witnessed at KARI-Thika in the present study. These findings reinforced the findings of Waiganjo *et al*. (2002) who suggested that the low yield and poor quality supply of bulb onions from Kenya was attributed to lack of appropriate pest management techniques among other factors.

The present study revealed that onions performed well in Mwea during the dry season compared to the wet season. Low onion yields were realized during the long rains probably due to prolonged flooding and increased incidences of bulb rot. The disease was quite common during the season. It was observed that land topography at Mwea was generally flat and the area had clay soils which made the area to be prone to flooding.

In Thika, yields were higher during the long rainy season compared to the dry season. This was probably due to less flooding during rainy season as a result of the common slopy topography observed at the site. There were also less incidences of bulb rot. The rainy season was characterized by low thrips load possibly due to the effects of rainfall where heavy rain was reported by Harris *et al.* (1936) to affect thrips population by washing them off plants and down to the soil surface, causing sudden sharp declines in their population density

The current study revealed that different onion varieties significantly differed in yield capacities. Texas Grano was shown to significantly outweigh other varieties in yield in protected and unprotected onion plots. Red Comet significantly registered the lowest yield in the unprotected plots and therefore was less tolerant to infestation by onion thrips. There were no significant differences in yield between Red Creole, Bombay Red and BSS 230 Hybrid. These findings were supported by findings of other scientists. For example, in similar work carried out in Tanzania, Msuya *et al.* (2001) reported that Texas Grano significantly produced the highest yield and the largest bulbs while the yield of Red Creole was significantly below average. Although Texas Grano had the highest yield, it was reported by Msuya *et al.* (2001) to have less pungent smell compared to the red onion varieties. In Kenya and indeed many other tropical and sub-tropical countries, red, pungent onions were reported by AVRDC (1993), Kimani and Mbatia (1993), Mohamedali (1994), Singh and Rana (1994), Vimala *et al*. (1994) and Mulungu *et al.* (1998) to be much more preferred than yellow or white, sweet onions. On basis of yield and pungency, Red Creole, BSS 230 Hybrid and Bombay Red were good varieties which could be recommended for cultivation in Kenya.

The present study revealed that the population densities of onion thrips at KARI-Mwea ranged from 0.98-1.60 and 2.02-3.35 thrips/plant for the wet and dry seasons respectively. On the other hand, the population densities recorded from KARI-Thika ranged from 2.78-8.38 and 4.51-9.29 thrips/plant respectively. It was noted that these numbers were not high enough to cause any significant loss in yield. This was in agreement with the findings by Waiganjo (2004) who established a minimum threshold of 19.6 onion thrips/plant as the density that was sufficient enough to cause significant loss of onion yield in Kenya. However, it was clear that infestation by onion thrips had the potential of causing economic losses in onion production. Increased loss of onion yield was registered at Thika trial site than at Mwea and this phenomenon corresponded well with the increased population densities of onion thrips noted for Thika. The highest loss in yield occurred at a time when the highest mean number of thrips per plant was observed.

Among the onion varieties tested, Red Comet gave the highest loss in yield although it had the lowest number of thrips. This meant that the variety was less tolerant to thrips injuries. BSS 230 Hybrid showed the second highest loss in onion yield in most instances. BSS 230 Hybrid significantly attracted the highest mean number of thrips per plant during the trial period at the two sites. Red Creole which was used as the local check was also quite susceptible to thrips as it registered the third highest loss in yield. Bombay Red although had significantly attracted the second highest number of thrips per plant gave a moderate loss in yield meaning that it was abit tolerant to thrips injuries. The lowest loss of yield was given by Texas Grano which had the second lowest number of thrips in most cases implying that its susceptibility level to onion thrips infestations was quite low. The loss in bulb yield due to attack of onion crop by onion thrips was in agreement with the findings reported by other authors. For instance, Kendall and Capinera (1987) reported that the most serious effect of infestation by thrips was the resultant reduction in bulb yield. Onion yield losses ranging between 18% and 60% in Kenya were reported by Waiganjo (2004).

The potential of various onion varieties in producing high quality onion bulbs for market was studied at Mwea and Thika experimental sites. The study focused on mean bulb diameter and mean bulb weight as variables determining onion market quality. The present research indicated that Mwea agroecological zone had a higher potential of producing quality onions compared to Thika zone. This could be a pointer as to why the zone was selected for promotion of commercial onion production in 1950s as reported by Kimani and Mbatia (1993). Results of the present research revealed that chemical thrips control and growing of onions during the rainy season could promote production of quality onions for market. These observations were tied to the low number of thrips associated with such conditions. It was shown in the present research that delayed peaking of thrips infestation until crop maturation period did not seriously affect onion quality as was evidenced at Mwea trial site during the second season.

In thrips controlled environment, there were no significant differences in onion bulb quality produced by the tested onion varieties save Red Comet which significantly produced the lowest quality bulbs. In a situation where thrips were uncontrolled, the results of the present study indicated that Texas Grano and Red Comet had the potential of significantly producing the highest and the lowest quality bulbs respectively. There were no significant differences in bulb weight and bulb diameter observed in other onion varieties. It was established from the present research that the percent reduction in onion grade two which was considered to be of higher market quality was positively related to the number of onion thrips attracted to the onion varieties. The effects of thrips infestations on onion market quality have been reviewed by many authors. For example, Tschirley *et al.* (2004) observed that the low yield and poor quality supply of bulb onions from Kenya was attributed to lack of appropriate onion thrips management techniques among other factors. Research by Sanderson (1995) demonstrated that thrips feeding had the potential to significantly reduce onion yields. The reduction was in form of smaller onion bulbs and occurred from feeding activity after bulbing.

In conclusion, it was established from the present study that infestations by high population density of onion thrips adversely affected the growing of onion crop. It was also clear that the number of onion thrips recovered at Mwea and Thika sites were not sufficient enough to cause any significant differences in yields between various onion varieties. It was established that more leafy onion varieties tended to harbour more thrips than the less leafy varieties. Further, it was evident that yield capacities of onion varieties were dependent on crop pest burden among other factors. Results indicated that Texas Grano produced the highest yield followed by BSS 230 Hybrid, Red Creole, Bombay Red and Red Comet in that order. Quality of onion bulbs was affected by the number of onion thrips infesting various onion varieties. Red Comet was least tolerant to injuries by onion thrips since it produced onion bulbs of the lowest quality inspite of the low thrip burden observed from the variety.

# CHAPTER 6

## 6.0 GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

### 6.1 GENERAL DISCUSSION

In Kenya, dry onion is the third most important vegetable crop for the domestic market, after brassicas and tomato. It is also an important source of income for small holder farmers and business community involved in local and cross border trade (Kimani *et al.*, 1990). Although favourable conditions for onion production exist in Kenya, the country experiences inadequate supply to meet local market demand. The shortfall is catered for by imports from neighbouring country, Tanzania (Mwendo *et al.,* 2004). In order to address onion production shortfalls in Kenya, there was a need to examine farmers' current practices with a view to identifying gaps in knowledge and skills and other constraints and suggest solutions.

It was apparent from the findings of the survey that there existed some disconnection between the farmers' practices and the recommended agronomic practices necessary for enhanced production of onions in Kenya. Although onion production was considered as the most important income generating enterprise by those engaged in its production, levels of production were low due to many production constraints. Many farmers significantly rated pests and diseases, lack of capital, unreliable onion market and weeds in that order as the most serious impediments to quality and quantity production of onions.

The present survey singled out onion pests and diseases as the most serious onion production challenges, the same findings which were expressed by farmers in an earlier survey in Kenya reported by Waiganjo (2004). In a survey to compare costs and returns of bulb onion production in Kenya and Tanzania, it was reported by Tschirley *et al.*, (2004) that high incidences of pests and diseases and high costs of agrochemicals among other factors were the major impediments to enhanced onion production in Kenya.

The problem of pests and disease control could be explained by lack of capital to buy the agrochemicals since majority of farmers were small operators with small parcels of land. The small land holdings could also have contributed to high incidences of pests and diseases due to lack of regular crop rotation programs. Many farmers were not aware of alternative pests and disease control options and their benefits. There was a need for farmers to reduce the over-reliance of pesticides and fungicides and adopt integrated pests control options since chemicals were costly besides their harmful effects to beneficial organisms and the environment. Training of farmers in onion pest and disease management was a necessity in the study area. It was also important to introduce to farmers onion varieties that had high yield capacities but less susceptible to attack by onion thrips.

Lack of capital was cited as an important onion production constraint. This problem was most likely due to small scale operation reported in the present study. Majority of farmers possessed small parcels of land. As food security measure, more land was devoted to growing of food crops and little was available for growing of onions. The small scale operation also limited economic use of farm machinery to boost onion production in the area. Lack of land title deeds by many farmers could have added its share to lack of capital. Many farmers could not access loans from commercial banks and other money leading institutions since land could not used as a collateral. As a means of alleviating problem of capital it was important that farmers be encouraged to allocate more land to growing of high value horticultural crops like onions instead of growing crops like maize and dry beans which had low gross margins and where the district has less comparative advantage. This would create better utilization of the scarce land and other resources common in the survey area. Land registration where title deeds were issued should be promoted to enable farmers to access credit from commercial institutions and also to be motivated to invest more in farm enterprises in terms of modern technology such as drip irrigation, and use of greenhouses to grow onions and other horticultural crops.

Onion marketing was perceived as the third most important impediment to enhanced onion production in the study area. According to the findings, there was lack of proper differentiation of onion grades that may have contributed to the low onion market prices offered to farmers. In addition, problems of price under-cutting could have been possible since middlemen or brokers formed the bulk of the onion buyers. In order to solve marketing inefficiencies, it would be recommended that onion farmers join co-operatives societies to improve on their bargaining power during onion marketing or when purchasing farm inputs. It would also be advisable for the gorvenment to facilitate formation of National Onion Growers Association of

Kenya to address more effectively and efficiently onion production and marketing functions such as grading, storage, financing, gathering of market intelligence and transportation. To improve marketability of onions, available post-harvest technologies should be fine-tuned and the information availed to farmers. To empower the onion growers, a competitive production cycle calendar for onion production should be developed and farmers trained on the dynamics of the local market.

In the present study, many farmers significantly ranked weeds as the fourth most important onion production constraint after pests and diseases, lack of capital and unreliable market. This revelation reinforced the findings of an earlier survey conducted in Kenya by Waiganjo (2004). The problems of weeds in the survey area could be explained by lack of capital to pay for labour costs and the high rate of weeds resurgence since the crop was mostly grown by irrigation. It, therefore, implied that efforts to solve problem of capital would also help to address the problem of weed control in the study area.

The present study revealed that onion thrips (*Thrips tabaci* Lindeman) was a dominant pest of onions in onion growing areas in Kenya. This finding was in agreement with work of other authors (Karel and Mueke, 1978; Waiganjo, 2004, Waiganjo *et al.,* 2006 Waiganjo *et al*., 2008). Apart from onion thrips, western flower thrips were also recovered from onion fields in Kirinyaga District, again confirming the findings of an earlier study in the same area reported by Waiganjo (2004). Effective use of insecticides to control thrips in onion fields in the study area was likely to be much more complicated by the presence of western flower thrips since the pest was reported to easily develop resistance to pesticides (Immaraju *et al.*, 1992; Gitonga, 1999; Waiganjo, 2004).

It was established in this study that onion varieties grown in Kenya had different levels of susceptibility to onion thrips infestations. This finding was consistent with work of other scientists who observed that onion varieties offered varying degrees of resistance to thrips (Coudriet *et al.*, 1979, Brar *et al.,* 1993) depending on leaf structure and growth form (Terry, 1997). Considering levels of susceptibility and yielding capacity, Texas Grano, BSS 230 Hybrid, Red Creole and Bombay Red could be recommended for direct deployment to onion growing areas in Kenya. Red Comet could be considered as a suitable candidate for future plant breeding programs because of the low number of thrips attracted to it. It also meant that introduction of onion pest resistant varieties in onion growing areas in Kenya should form part of IPM strategy to deal with onion pests.

The present study indicated that high temperatures and low rainfall tended to favour high population densities of onion thrips while high rainfall and low temperatures tended to reduce the level of infestation on various onion varieties. These conclusions seemed to be in agreement with the findings reported by Lorini and Junior (1990) who concluded that high temperature and lack of rainfall increased the population densities of thrips since high temperatures favoured rapid multiplication of onion thrips and heavy rainfall washed off the thrips from plants. This finding would help in the choice of the most suitable areas for onion production in Kenya. The reasons why there were more thrips at KARI-Thika than at KARI-Mwea despite of the relatively low temperatures and high rainfall at KARI-Thika were not very clear and required further investigation.

The present study revealed that the extent to which onion leaves were damaged by onion thrips depended on their numbers on the crop. In the protected plots, the damage of onion leaves by onion thrips was found to be significantly lower than in the unprotected ones. This implied that the pesticides used in the protected plots were of high efficacy since they were able to check the population of onion thrips on the crop. This was in agreement with the findings reported by Muriuki (1982) and Waiganjo (2004) who concluded that several insecticides were effective in the control of onion thrips in Kenya. In onion farms, pesticides should form part of the integrated pest management strategy for the control of onion thrips.

It was observed in the present study that there existed significant differences in damage of onion leaves by thrips between onion varieties. The highest damage levels recorded for BSS 230 Hybrid and Bombay Red were best explained by the higher number of onion thrips recovered from the varieties. The bushy growth habits of these varieties might have been advantageous to onion thrips by providing better hiding places as reported by Fournier *et al.* (1995). The lowest level of damage of onion leaves by thrips was noted for Red Creole. It was possible that the popularity of Red Creole among many onion farmers in Kenya was attributed to low damage by thrips.

BSS 230 Hybrid and Bombay Red onion varieties were found to have higher incidences of onion fungal diseases compared to other varieties. Texas Grano was found to be the most susceptibe to onion diseases although it had the second lowest number of thrips attracted to it. The reasons for the high susceptibility to diseases were not very clear and required further investigation. Red Creole was found to be the least susceptible to onion fungal diseases, a characteristic which could have contributed to its popularity in Kenya. High number of thrips generally tended to be associated with higher incidences of onion foliar diseases, a finding that was also reported by Waiganjo (2004). This was because feeding injuries by thrips predisposed the plant tissues to subsequent invasion by bacterial and fungal pathogens as reported by Lewis (1997).

The present investigation revealed that generally, the lowest number of onion thrips for all the varieties included in the study occurred during the early stages of crop growth but as the crop matured, the number of onion thrips steadily increased to peak during 60-90 days after transplanting and therafter the numbers went down. This implied that bulb enlargement onion growth stage (3 months after transplanting) was the most critical when control methods for onion thrips should be intensified. These findings were in agreement with results of earlier experiment conducted in Kenya, where it was reported by Waiganjo (2004) that the highest number of onion thrips occurred during the bulbing and bulb enlargement stages while the lowest numbers were observed during the pre-bulbing and bulb maturation growth stages.

Investigations to assess the effects of thrips on onion yield revealed that increased thrips load lead to increased yield loss for all the onion varieties tested. This finding was consistent with work of other scientists who reported that the most serious effect of thrips infestation is the reduction in bulb yield (Coviello and McGiffen, 1995; Waiganjo, 2004). This finding, therefore, meant that onion thrips control is important for increased production of onions in Kenya. The present study indicated that yield potential of onion varieties grown in Kenya is dependent on many factors including the agroecological zone, the crop pest burden and the season. The results indicate that all the varieties had a higher yield potential at Mwea agroecological zone than at Thika zone. This therefore meant that onions do well in Mwea than in Thika. This finding seems to suggest one of the reasons why Mwea was selected in the campaign for enhanced production of bulb onions in 1950s (Kimani and Mbatia, 1993).

It is also evident from the results of this investigation that majority of onion varieties available in Kenya had the potential of producing more than 30 ton/ha in a situation where all recommended agronomic practices are observed where onion thrips were controlled. The observed high yield potential was far above the world average of 17.7 t/ha reported by Msuya *et al*. (2001) and was comparable to high yields realized in countries like China, Spain and Japan reported by FAO (1999). However, in an agroecological area where the thrips burden was high, yields fell drastically. The study revealed also that different onion varieties significantly differed in yield potential. Texas Grano was shown to significantly outdo other varieties in yield. Red Comet significantly registered the lowest yield and was least tolerant to thrips infestation. There was no significant difference in yield potential between Red Creole, Bombay Red and BSS 230 Hybrid. On basis of yield and pungency, Red Creole, BSS 230 Hybrid and Bombay Red are important varieties which could be recommended for cultivation in Kenya. The present study indicated that the loss of bulb quality due to thrips was significantly lower for Texas Grano compared to all other varieties. It, therefore, meant that this variety was the best to grow for markets where strong pungency was not a quality factor.

**6.2 CONCLUSIONS**

The following findings were noted during the field survey:

(i) Many young school leavers were being attracted to onion farming as a way of obtaining gainful employment and income.

(ii) The literacy level among onion growing farmers was average.

(iii) Majority of the farmers lacked the necessary financial resources and capital assets that would enhance onion production.

(iv) Many farmers integrated growing of crops with keeping of livestock as a way of diversification and also to benefit from farmfard manure produced by livestock.

(v) Many onion growing farmers possessed small percels of land which discouraged effective crop rotationprograms for pests and disease control and also limited economic use of farm machinery.

(vi) Food security was a major preoccupation amongst the farmers in the study area.

(vii) Almost half of farmers lacked title deeds for their farms and therefore could not use land as collateral to secure loans from commercial banks and other money lending institutions for farm improvements.

(viii) Onions were ranked as the most important income generating enterprise

(ix) Soil sampling and testing was not a common practice among onion growing farmers and the nutrient levels and other problems of the soil were not well understood by farmers involved in the study.

(x) Weeds were ranked as the fourth most important onion production impediment after pests and diseases, lack of enough capital and unreliable onion market.

(xi) Thrips were the most common insect pest of onions followed by cutworms.

(xii) Pesticides use was the dominant method of insect pests control in onion farms.

(xiii) Downy mildew and Purple blotch were the most common onion diseases although bulb rot was becoming rampant.

(xiv) There was low adoption rate for alternative methods of pests and disease control in onion farms.

(xv) Local traders and middle men formed the bulk of onion buyers.

The following important findings were established during the field trials at KARI-Mwea and KARI-Thika:

(i) Onion thrips (*Thrips tabaci*) was the dominant thrips species infesting onions in onion growing areas in Kenya

(ii) Apart from onion thrips, western flower thrips (*Frankliniella occidentalis*) were also recovered from onion fields in Kirinyaga District.

(iii) Pesticides were able to keep thrips population to a minimum in the protected onion plots.

(iv) BSS 230 Hybrid onion cultivar was shown to significantly attract the highest number of thrips and Red Comet significantly attracted the lowest number of thrips. Bombay Red and Red Creole displayed medium susceptibility to thrips while Texas Grano was less susceptible.

(v) More thrips were recovered from onion plants grown at Thika than at Mwea.

(vi) Damage done on leaves of onions depended on the number of thrips infesting the varieties. The highet levels of pest damage were observed from BSS 230 Hybrid and Bombay Red while the lowest was recorded by Red Creole.

(vii) Red Comet was shown to suffer the greatest loss of growth despite the low numbers of thrips attracted to it. Texas Grano suffered the least loss of growth corresponding to the low number of thrips recovered from the variety.

(viii) Texas Grano had the highest yield capacity while Red Comet had the lowest capacity. BSS 230 Hybrid, Red Creole and Bombay Red had the same yield capacities.

(ix) In an environment where thrips were controlled and where all recommended agronomic practices were followed, all onion varieties tested had potential of yielding more than 30ton/ha which was comparable to yields realized in leading world onion producing countries.

(x) Increased thrips load led to increased loss of onion yield. Red Comet gave the highest loss of yield although had the lowest number of thrips meaning that the variety was less tolerant to thrips injuries.

(xi) More thrips numbers were attracted to onion crop during bulb enlargement period.

(xii) Weather parameters particularly temperature and rainfall had influence on thrips population density on onion plants. High temperatures tended to promote an increase in the number of thrips but the converse was true for rainfall. However, there were more onion thrips at Thika than at Mwea despite the latter registering higher temperatures and low rainfall.

(xiii) Increased number of onion thrips tended to promote occurrence of fungal diseases in onions. However, Texas Grano was highly susceptible to fungal diseases despite harbouring low number of thrips while Red Creole was the least susceptible to diseases.

(xiv) Texas Grano had capacity of producing onions of high quality while Red Comet had the lowest capacity.

## 6.3 RECOMMENDATIONS

Timely implementation of the following recommendations could assist in alleviating onion production challenges faced by farmers and increase production:

- There was need to invest on and promote sustainable sources of farm power especially use of draft animals to minimize drudgery while carrying out farm operations.
- Farmers should invest on capital assets that would raise the level of farm mechanization in the area.
- More land should be allocated to growing of high value horticultural crops such as onions instead of growing crops like maize and dry beans which had low gross margins and where the district had less comparative advantage. This would create better utilization of the scarce land and other resources common in the survey area.

- It was important to introduce to farmers onion varieties that had high yield potential but less susceptible to thrips infestation.
- Periodic soil fertility evaluations through soil sampling and testing should be carried out to determine the nutrient status of soil since the area was characterized by intensive cropping system.
- Use of inorganic fertilizers and organic manures should always be based on recommendations from soil fertility evaluations carried out from time to time.
- Training farmers on monitoring thrips infestation and determining the best time to control would assist farmers to avoid routine application of pesticides, common in the area.
- Farmers should be sensitized on the need to observe Good Agricultural Practices (GAP) as a way of enhancing food safety.
- Marketing of onion should be improved by farmers joining co-operative societies and also addressing more effectively and efficiently marketing functions such as grading, storage, financing, gathering of market intelligence and transportation.
- Land registration where title deeds were issued should be promoted especially in Mwea Division for farmers to access credit from commercial institutions and also to be motivated to carry out major farm improvements.

- A strategic plan for the improvement of onion production in the study area should be formulated. An annual work plan should be extracted from the strategic plan mentioned above and an implementation matrix for various performance indicators prepared and implemented.
- To empower the onion growers, a competitive production cycle calender for onion production should be developed and farmers trained on the dynamics of the local markets.
- The most economical method and frequency of weeding for the area should be established and the information relayed to farmers since weed control was a major production constraint in the area.
- The relationship between onion crop damage due to thrips and weeds common in the study area should be investigated and results made available to farmers.
- There was need to do more studies on the most effective and economical method and frequency of irrigation of onions in the study area. The study should also focuss on the effects of the various methods of irrigation on thrips control.
- There was need to determine thrips economic injury levels in order to establish an effective control strategy for the area.
- Evaluation of cost effectiveness and efficacy of common insecticides and fungicides used for control of onion pests and diseases in the study area

should be carried out. Cases of resistance development should be assessed during the study.

- Control of bulb rot, a disease that wasrampant in the area, should be addressed.
- An onion growers' manual or handbook should be prepared and availed to farmers.
- National Onion Growers Association should be formed to promote production and marketing of onions in Kenya.
- To improve marketability of onions, available post-harvest technologies should be fine-tuned and the information availed to farmers.
- Farmers should be trained more regularly on records keeping and modern methods of farming and technological advancements in onion production. Enhanced farmer training could be achieved through improved local agricultural extension services, regular attendance to field days and shows. Support of initiatives such as establishment of farmer field schools where research findings were effectively transfered to onion growing farmers would also help to fill existing gaps of knowledge and skills. Other regular outreach programmes for dessimination of knowledge and skills on onion production should be organized or prepared and these to include web sites, field days, agricultural shows, posters, newspapers, journals,workshops and conferences.

- The present survey should be closely followed by another survey conducted in the same area to evaluate the implementation impact of some of the suggested recommendations.
- Red Comet which displayed least susceptibility to thrips could be considered as a suitable candidate for future onion crop improvement through plant breeding.
- There was need to enhance onion production in Mwea agroecological zone since the region had a lower thrips burden than Thika agroecological area.
- Texas Grano, BSS 230 Hybrid, Bombay Red and Red Creole were good varieties which could be recommended to be grown by farmers in Kenya.
- Thrips control measures should be initiated at the onset of the bulbing period and sustained until crop matures.
- More studies should be done on seasonal abundance of Western Flower Thrips in onion farms in Kenya.
- An important aspect of priority research would be to establish the temporal population dynamics of thrips in onions in order to devise the best time to control them and also to establish the best sampling time
- The reasons why thrips were more abundant at Thika than at Mwea should be considered for future research.
- The mechanism for the low foliar damage by onion thrips observed from Red Creole should be a subject for further research

- More studies should be done to determine the cause of the high susceptibility of Texas Grano and the low levels of susceptibility in Red Creole to onion foliar diseases.

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# APPENDICES

**Appendix 1:** Questionnaire for Baseline Survey of Bulb Onion Crop Management and Marketing Practices in Kirinyaga District, Kenya**.**

**SCREENING QUESTION:** Have you been actively involved in bulb onion production for three years?

**I**f no, do not interview: replace with another farmer.

**1. GENERAL INFORMATION**

Date of interview ______________________________________________

Enumerator______________ Division _______________________

Location ________________ Village _________________________

Distance to all weather road (Km) ________________________________

Distance to the nearest market (Km) ______________________________

Distance to the nearest agricultural extension office (Km) _______________

Name of Interviewee_________________________________________

Name of household head ______________________________________

**2. BACKGROUND INFORMATION**

(ii) Farmer information

| Name | Age (Years) | Main occupation | Secondary occupation | Education (years) |
|---|---|---|---|---|
| Interviewee | | | | |

Occupation

1= Farmer 2= Church work 3= Casual laborer 4= Student

5= Civil servant 6= Business person 7= others (specify)

Education

1= Tertiary 2=Secondary 3=Primary 4=Informal skills

5=none

**3. WEALTH STATUS OF FARMER**

- Do you own the following assets ?

| Item | Yes | No |
|---|---|---|
| Knapsack sprayer............. | ........................................ | ...................................... |
| Water pump. ................. | ........................................ | ...................................... |
| Water tank.............. | ........................................ | ...................................... |
| Milk cow.......................... | ........................................ | ...................................... |
| Bull............................. | ........................................ | ...................................... |
| Oxen............................... | ........................................ | ...................................... |
| Ox-cart............................... | ........................................ | ...................................... |
| Ox-plough............................ | ........................................ | ...................................... |
| Bicycle......................................... | ........................................ | ...................................... |
| Vehicle.............................. | ........................................ | ...................................... |
| Solar panel....................................... | ........................................ | ...................................... |
| Electricity....................................... | ........................................ | ...................................... |
| Tractor.................................... | ........................................ . | ..................................... |

- Information on land use:

a) What is your total farm size (own) in acres? ____________

b) What is the land size under food crops in acres? ________

c) What is the land size under cash/ hort. crops in acres? ________

d) What is the total available land size under onion in acres? ________

- Do you have a title deed for your land? ______ 1=Yes 2=No
- Do you lease land to grow onions? _______ 1=Yes 2=No

  If yes how many acres? _______

- What would you rank as the top 5 enterprises in your farm according to?

  (i) Income generation

  (ii) Family food availability

| ENTERPRISE | |
|---|---|
| Income generation | Family food availability |
| 1. | 1. |
| 2. | 2. |
| 3. | 3. |
| 4. | 4. |
| 5. | 5. |

**4. CROP MANAGEMENT PRACTICES**

a) Manure use

| Type of Manure | Rate (Kg/ha) | Method of application | Cost (Ksh |
|---|---|---|---|
| | | | |
| | | | |

Reasons for not using manure (for those not using) ____________________________

1=too costly 2=not necessary 3=No returns 4=not aware

5=other specify________

b) Weed Control

Type of weeds if known________

Method of weed control ___________1= mechanical 2=chemical 3=other

Cost___________

If mechanical, type of implements (e.g. Panga or jembe) ___________

If chemical, which herbicides? ___________

Stage of herbicide application_____________________________________________

Weeding frequency in a season__________________________________________

c) Irrigation

Type of water___________________________________________________

Method of irrigation______

1=rain fed 2=bucket 3=furrow 4=Overhead/sprinkler 5=drip 6=other

Irrigation frequency in a week/month/ ----------------------------------

If Rain fed, why?

1=readily available 2=cost effective 3=cannot afford alternative irrigation methods

4=other specify____________________

d) Soil fertility evaluation

Have you ever taken your soil for fertility evaluation?

If yes, where?___________________

Cost_______________________

When (last)________________________ If not, why? __________ 1= too costly 2=not relevant 3=not aware 4=other specify_______________________________

e) Crop protection

- Pests and their Control

| Name of pest | Severity | Onion stage | Management |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

1 = Pre-bulbing 2 = Bulbing 3= Bulb enlargement 4= Bulb maturation.

1= (>50% infestation) 2= Moderate (>20% ≤ 50%) 3=Scarce (≤20%) 4=none (no infestation)

- Diseases and their control

| Name of disease | Severity | Onion stage | Management |
|---|---|---|---|
| | | | |
| | | | |

1 = Pre-bulbing 2 = Bulbing 3= Bulb enlargement 4= Bulb maturation.

1= (>50% infestation) 2= Moderate (>20% ≤ 50%) 3=Scarce (≤20%) 4=none (no infestation)

- Pesticide Use

  - Name the pesticides most frequently used and your experiences

| Pesticide used | Efficiency |
|---|---|
| 1. | |
| 2. | |
| 3. | |

1=highly effective 2= Moderate 3= Not effective

- Alternative pest control

- Do you use any other method of pest control apart from chemical pesticides?

| Method used | Efficacy | Reason |
|---|---|---|
| | | |

1= Highly effective 2= Moderate 3= Not effective

- Between the two above methods of pest control which one is more suitable? ____

  1= Pesticide use 2= Alternative method of pest control

  Why? ----------------

- Are you aware of the following Good Agricultural Practices (GAP)?

**5. ONION HARVESTING AND POST -HARVEST PRACTICES**

a. When do you know that your onions are ready for harvest? _______

b. How do you do the curing?__________

c. Mode of harvesting __________

d. How do you carry your produce from the field? ___________

e. Do you have a grading/ packing shed or area? ______1= Yes 2= No

f. How close to the field? _______

g. Do you sort after harvesting? ________1= Yes 2= No

h. If yes what do you sort? _________1= size 2= pest and disease damage3=colour

i. 4= other specify_________

j. Who does the grading? __________1= Farmer 2= Broker 3= Buying company

k. Into what grades? specify____________

l. Do you store the onions after harvest? ______1= Yes 2= No

m. For how long? Specify ____________

n. How do you store?____________

**6. ONION MARKETING**

- Which is the harvesting season for onions in a year? ( month/ Month to month)
- How often do you sell your onions per month during the harvesting season?______ 1= Once every month 2= twice every month 3=three times every month 4=four times every month 5=other specify______
- Who do you sell to?_______

- Does the buyer have specific demands? _______1= Yes 2= No

  If Yes, specify________

- What market arrangements do you have with the buyer/broker? ______1= Cash payment 2=Fortnightly payment 3= Contractual agreements

- What price do you receive?

| Year | Lowest price (Ksh/ Kg) | Highest price (Ksh/ Kg) | Reason |
|---|---|---|---|
| | | | |
| | | | |

**7. ONION PRODUCTION CONSTRAINTS**

Mention at least 5 onion production constraints starti ng with the most important.

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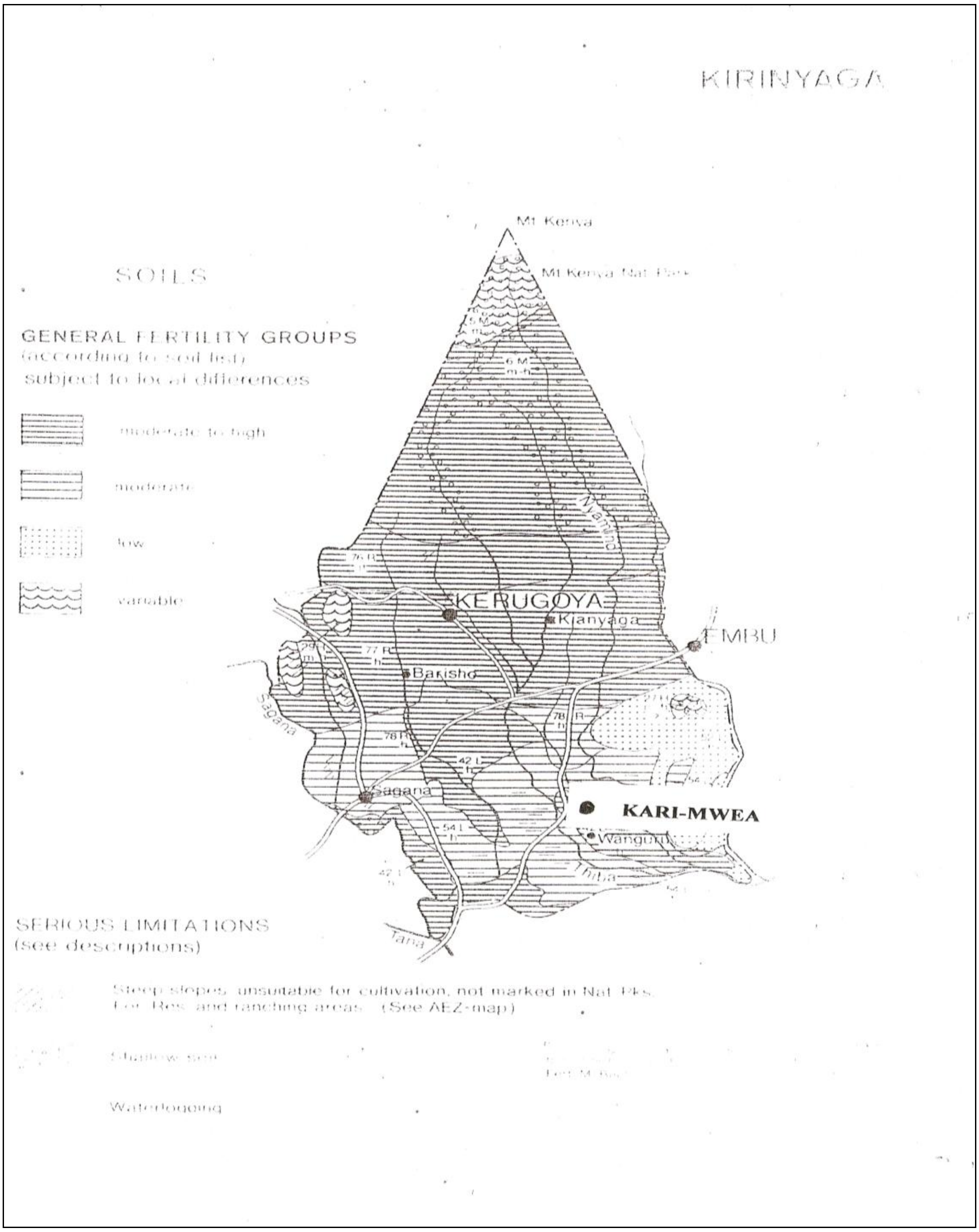
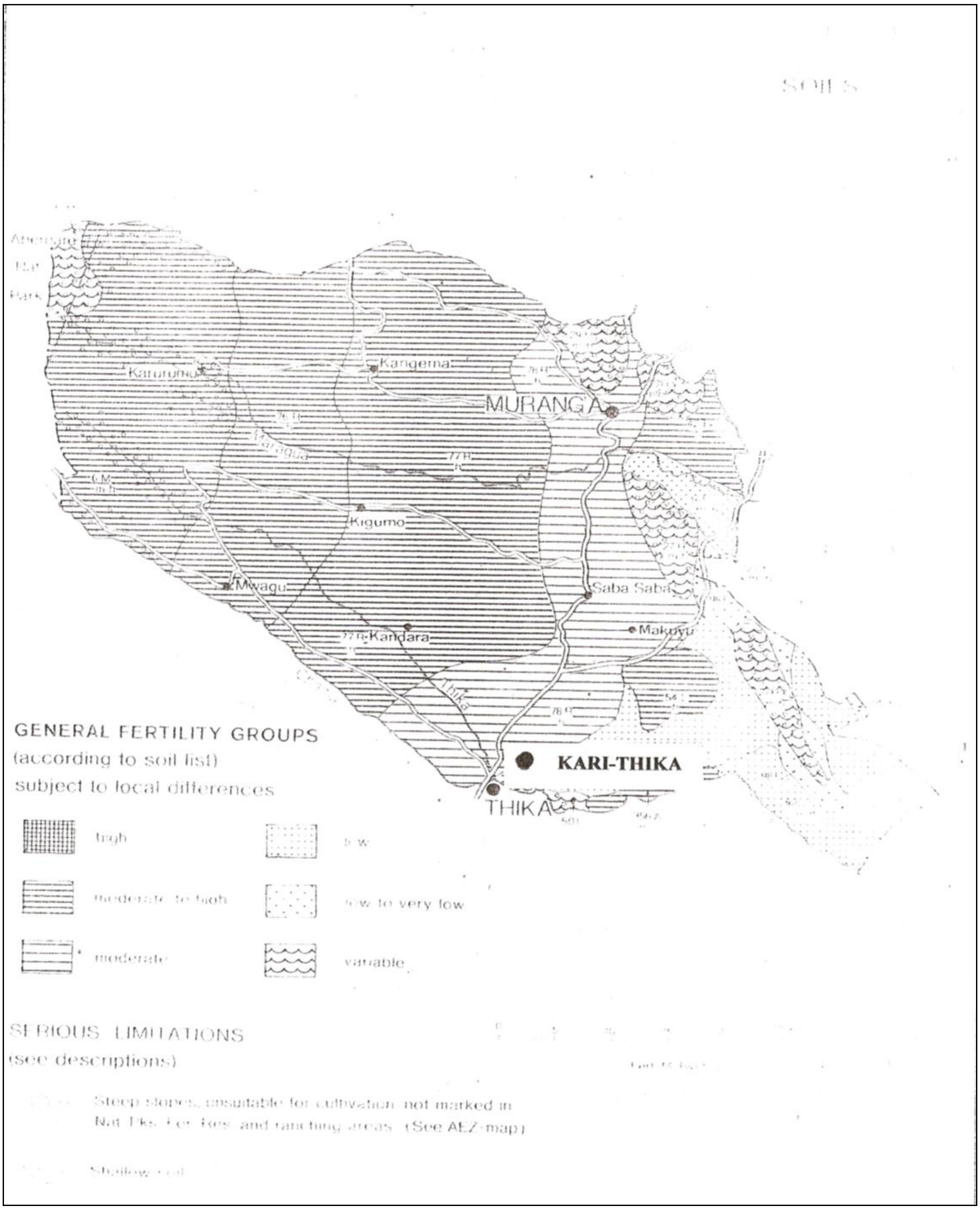
**THANK YOU FOR YOUR KIND AND VALUABLE CONTRIBUTION**

**Appendix II:** Map showing location of KARI- Mwea experimental site in Larger Kirinyaga District, Kenya




*Adopted from:* Jaetzold and Schmidt (1983)

**Appendix III:** Map showing location of KARI- Thika experimental site in Larger Muranga District, Kenya




*Adopted from:* Jaetzold and Schmidt (1983)

**Appendix IV:** Soil Test Report: Interpretation and Fertilizer Recommendation for KARI-Mwea and KARI-Thika Experimental Sites

**Kenya Agricultural Research Institute**

**National Agricultural Research Labs.**

P.O. Box 14733-00800, Tel: 4444137, 4444251/52

NAIROBI

**SOIL TEST REPORT**

| | |
|---|---|
| Name | Dr. Monica Waiganjo |
| Address | KARI - Thika |
| Location of farm, town or village and district | |
| Date sample received | 31/01/07 |
| Date sample reported | 07/02/07 |
| Reporting officer (through Director NARL) | A. Chek |

Chek

| | Soil Analytical Data | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Field or plot** | **Mwea** | | **Thika** | | | | | |
| Lab. No/2007 | 269 | | 270 | | | | | |
| Fertility results | value | class | value | class | value | class | value | class |
| Soil pH | 4.93 | strong acid | 5.60 | medium acid | | | | |
| Exch. Acidity me% | 0.6 | adequate | | | | | | |
| Total Nitrogen % | 0.12 | low | 0.11 | low | | | | |
| Org. Carbon % | 1.64 | moderate | 1.44 | moderate | | | | |
| Phosphorus ppm | 14 | low | 239 | high | | | | |
| Potassium me% | 0.92 | adequate | 1.39 | adequate | | | | |
| Calcium me% | 2.3 | adequate | 3.9 | adequate | | | | |
| Magnesium me% | 1.44 | adequate | 4.98 | high | | | | |
| Manganese me% | 1.08 | adequate | 0.59 | adequate | | | | |
| Copper ppm | 2.95 | adequate | 2.13 | adequate | | | | |
| Iron ppm | 54.6 | adequate | 16.4 | adequate | | | | |
| Zinc ppm | 4.26 | low | 6.04 | low | | | | |
| Sodium me% | 0.08 | adequate | 0.12 | adequate | | | | |

**Interpretation and Fertilizer Recommendation.**

**Mwea:** The soil reaction is acidic. Soil is poorly supplied with nitrogen, phosphorus and zinc. The organic matter content is moderate. At planting time apply 2 t/acre of well decomposed manure or compost and 120 kg/acre of compound N:P:K fertilizer 23:23:0. Commercial liquid fertilizer (foliar feed) which contains zinc should be used on growing crops in order to control the deficiency. **Thika:** The soil reaction is favourable for crops' growth. Soil is poorly supplied with nitrogen and zinc. The organic matter content is moderate. At planting time apply 2 t/acre of well decomposed manure or compost and 60 kg/acre of urea. Commercial liquid fertilizer (foliar feed) which contains zinc should be used on growing crops in order to control the deficiency.

**NOTE:** Test results are based on customer sampled sample(s).

Page 1 of 1