PARTICIPATORY ACTION RESEARCH AND TESTING THE EFFECTIVENESS OF STINGING NETTLE AS A BIOPESTICIDE IN KENYA

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ABSTRACT

Globally 50% of all food and cash crops are lost to pests and diseases. The participatory action research model has been effectively used to control the pests and diseases in developing countries. During the summer of 2006, an experimental study was carried out in Kamweti village of Central Province in Kenya with two major objectives: (1) To identify training needs on sustainable agriculture and organic farming principles through carrying out needs assessment consultative workshops and develop and execute training workshops based on identified training priorities; and (2) to investigate the efficacy of stinging nettle as a bio-pesticide in the most commonly grown vegetables. A total of 23 training workshops were carried out to train farmers on organic farming and sustainable agriculture principles. A total of 28 soil samples were tested for pH, nitrogen, phosphorus and potassium. From the soil analysis results, 95% of the soil samples resulted in low nitrogen levels, slightly acidic, low phosphorus levels and high potassium levels. The efficacy of stinging nettle was tested by comparing fresh biomass weight, plant growth, pest damage levels and abundance of pest species. Two treatments were arranged in a Generalized Randomized Block Design (GRBD) with four replications per treatment. Stinging nettle pesticide resulted in a significant reduction in pest damage levels on the treated plots in comparison to the control plots. However, there were no significant differences in biomass weight and plant height between the plots treated with the stinging nettle pesticide and the control. A total of 12 arthropod species belonging to five orders were observed with aphids being the most abundant species noted in the field. It is concluded that application of Stinging nettle extract reduced the crop losses due to pest damage and increased marketable yield for consumption and profit to smallholder farms in Kenya.

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CHAPTER 1: INTRODUCTION

With escalating population growth, food demand is expected to increase substantially during the coming decades (Pinstrup 1998). According to FAO (2005) population estimate, Africa's projected annual growth rate of 2.8 percent will double Africa's population in the next 25 years. To avoid additional food insecurity problems will call not only for increasing food production, but also for minimizing losses due to pests and diseases is needed (Pinstrup-Andersen et al. 1997; Pinstrup 1998; Lenne' 2000). The damage both to growing plants and stored plant products is enormous and a substantial proportion of all food crops grown is lost to insects each year (Lamb 1974). Focusing on curbing food loss due to diseases and pests is a wise use of time, energy and money (Yudelman et al. 1998). Pre-harvest and post-harvest pests account for 50% of all food and cash crops losses in the world (Sweetmore et al. 2001; FAO 2003a; FAO 2003b; Lenne' 2000). Worldwide crop losses due to pests (insects, diseases, nematodes, mammals, birds and weeds) account for 37%, of which 13% is due to insect pests (FAO 1975; Nyarko 1994; Pimentel and Goodman 1978).

Mitigating these losses continue to be a challenge among small scale and large scale farmers alike. Over time, synthetic chemical pesticides for pest management have been promoted as part of agricultural technology packages, along with high yielding crop varieties, irrigation, fertilizers and mechanization (Barfield and Stimac 1980). This technological innovation emerged during the Green Revolution, which in turn created multifaceted insect problems (Thrupp 2000; Glass and Thurston 1978). Before the Second World War, pesticides consisted of products both from natural sources such as nicotine, pyrethrum and inorganic chemicals such as sulfur, arsenic, lead, copper, and lime. The change from polyculture to monoculture systems of farming interrupted the indigenous ways of pest management and led to development of synthetic pesticides (Barfield and Stimac 1980). Pimentel and Goodman (1978) reported that outbreak levels of aphids, caterpillar populations and flea beetle occurred in *Brassicae oleracea* L. planted in monoculture but not when grown in mixed planting. Similarly, Altieri et al. (1983) found that beans grown in dicultures with corn had 25% fewer leafhoppers adults (*Empoasca kraemeri* R. and M.) than in monoculture. Traditionally, farmers planted multiple crops as intercrop, some of which acted as insect repellents. An example of a common crop protection method is planting kale with chilies and onions that act as repellents against diamondback moth (Tvedten 2007).

Synthetic pesticide use among poor, small scale farmers is limited due to high costs. In addition, pesticide use has unforeseen side effects, such as toxicity to non-target organisms, development of pest resistance and environmental contamination with potential to affect the entire food chain including human beings (Gould 1991; Glass and Thurston 1978). Ahmed and Graine (1986) have reported that lack of understanding of proper use of synthetically produced pesticide; and adulteration, unavailability of suitable application equipment and inadequate storage conditions are additional problems associated with the use of synthetic pesticide. High synthetic inputs, which are aimed at increasing food production, have resulted in continuous resurgence of pests in the field. Other problems include increased maximum residue levels of chemicals in most of the agricultural foods products and increased cost of production (Edwards 1990; Thrupp 2000). All of the above dangers associated with chemical use calls for the need to develop farmers' capacity to utilize other low-cost technologies that are environmentally friendly and locally available in order to increase food security.

A method of combating pests in agriculture that preserves the environment, minimizes health and economic risks is through natural pest management (Yudelman et al. 1998). Natural pest management strategies are technological approaches, which do not depend on synthetic chemical pesticides include plant breeding, biological control, biotechnology, botanicals and cultural measures (Pinetel 1991). In nature, plants develop defense mechanisms and toxicity to protect themselves against insect pests by producing repellent aromatic compounds that work as deterrents (Tvedten 2007). Low input agricultural systems that employ such plants with natural pesticides and repellents would reduce costs of food production in many developing countries (Pepetto 1985). Plants containing more than one bio-toxin are harder for insects to develop resistance to than a single compound found in most synthetic pesticides (Perimetel and Lavitus 1986).

Small scale farmers are increasingly using indigenous practices such as plant extracts to control pests and diseases on crops. In addition, large scale growers for export markets are looking for alternatives to synthetic pesticides as importers in temperate countries impose increasingly tight restrictions (including zero tolerance levels) of many widely used insecticides (Verkerk 1998).

In many African cultures, botanical pesticides and herbs have been used historically for medicinal and veterinary purposes, for protection of crops and stored products. However, in recent decades, adoption of these traditional approaches of crop protection as well as their possible improvement through the contribution of contemporary scientific methodologies has been generally limited. Constraints to increased adoption of botanical extracts by farmers include the absence of scientific validation, lack of support for botanical use by extension services, and the perception by many farmers of botanical use as being primitive. Only two botanical products, pyrethrum from C*hrysanthemum cinerarifolium L.* (in the family Asteraceae) and neem from *Azenderachta indica* L. (in the family Meliaceae) have been scientifically validated for crop protection (Ahmed and Graine 1986). Products from these two plant species have been commercialized as pesticide products worldwide.

Kenyan farmers have been using herbal remedies to control pest and diseases since the beginning of agriculture. While *Azederachta indica* and *Chrysanthemum cinerarifolium* are well documented for crop protection, these two species are not native to Kenya. There is a need to use indigenous and locally available species for crop protection because using locally available species have great potential in improving sustainable livelihoods of farmers through increasing their knowledge, income and other environmental benefits. Farmers who are actively developing such practices through trial and error should be encouraged because the knowledge that they obtain will have economical and environmental benefits to their families and local communities. In addition, finding the most economically viable and environmentally friendly solution to agricultural pests and diseases would benefit not only the environment but also increase scientific knowledge which is a benefit to all human kind.

In Kenya, there are indigenous communities that are trying to utilize local species in pest and disease control. One such community is Kamweti, a Kikuyu community living on the slopes of Mount Kenya. The Kamweti community has experimented with local stinging nettle species (*Urtica diversifolia L.*) as a potential biopesticide for use in production of local vegetable crops. The group expressed considerable interest in developing stinging nettle pesticide as an income generating product of microenterprise. In order to further develop the potential of nettle as a cash crop, the efficacy of stinging nettle as a pesticide needed to be scientifically documented. In order to further small scale organic production and self sufficient enterprise development, this validation must be done in a participatory and empowering manner. This thesis project addressed this need.

OVERALL GOAL

The overall goal of the study is to improve the livelihoods of an indigenous community in Kenya by increasing food production and agroeconomic levels through training on sustainable agriculture and microenterprise development. To accomplish this goal the specific objectives are to identify training needs on sustainable agriculture and organic farming principles through carrying out needs assessment consultative workshop and develop and execute training workshops based on identified training needs; and to investigate the efficacy of *U. diversifolia* as a biopesticide.

OBJECTIVES

The specific objectives for this study are:

1. To identify training needs on sustainable agriculture and organic farming principles through carrying out needs assessment consultative workshop and develop and execute training workshops based on identified training priories; and

2. To investigate the efficacy of *U. diversifolia* (stinging nettle) as a biopesticide in the most commonly grown produce: collard green; (*Brassica oleraceae* L. var. acephala cv. Georgia); tomato *(Lycopersicon esculentum* L. cv. Moneymaker); Swiss chard (*Beta vulgaris* var. cicla cv. Fordhook Giant); and French beans (*Phaseolus vulgaris* L. var. Julia).

CHAPTER 2: LITERATURE REVIEW

Farmer Participation

Several studies have acknowledged the role of farmer participation in agricultural development (Andrews et al. 1992; Biggs and Clay 1981; Thrupp 2000; and Richard 1989). According to Andrews et al. (1992), the success of any pest management technique is dependent on the level of farmer participation. Farmers have an enormous amount of indigenous knowledge in pest management (Berkes et al. 2000; Merwin 1995). Farmer-led research provides a real opportunity for the development of highly effective pest management strategies involving the use of botanical extracts, based on effective use of indigenous knowledge, farmer experience and scientific methodology and techniques (Verkerk 1998). Traditional methods of crop protection such as host plant resistance, cultural and biological control have been in existence since the beginning of agriculture (Glass and Thurston 1978). Most of these methods were developed through centuries of trial and error, natural selection and keen observation by farmers (Abate 2000). According to Shea (2002), traditional farmers have been successful in improving their pest management strategies through passive adaptive management practice despite the complexity of nature. Huang and Yang (1987) and Andrews et al. (1992) have reported that farmers in China effectively manipulate ants for control of pests in citrus trees. Other studies have noted that Asian farmers use ducks to control paddy pests and weeds (Borromeo and Deb 2006).

Traditional ecological knowledge which is based on learning by doing is similar to adaptive management (Bennun et al. 2005; Berkes et al. 2000; and Moller et al. 2004). Adaptive management approach is like a scientific method of study applied to management type settings (Walters 1986; Meffe et al. 2002; Moir and Block 2001). The traditional systems of monitoring the ecosystem changes are founded on local understanding of the ecosystem and are developed through the trial and error method (Berkes et al. 2000). Traditional ecological knowledge is very vital in partnerships especially in observations of extreme events which science might miss due to a short sampling period (Moller et al. 2004). Due to the complex nature of ecosystems, conventional scientific approaches alone may not be enough to address the problems (Bennun et al. 2005). Observations by Moller et al. (2004) suggested that participatory approaches require scientist to work with the local people because complex adaptive system problems involving human uses and impacts, cannot be separated from issues of value, equity, and social justice. Case studies on evaluation of monitoring and evaluation in participatory research carried out by a Consultative Group on International Agricultural Research (CGIAR) in Malawi, Uganda and Nigeria confirmed that farmers are more likely to adopt technologies that require little change to existing practice (Douthwaite et al. 2003). Failure to involve smallholder farmers in strategic planning of the investigation has been identified as a major limiting factor to the success of integrated pest management research and development in developing countries (Andrews 1992). More studies have shown that farmers actively contribute more than half of the ideas to on-farm experiments when cultural methods of pest control were studied (Thrupp 1989). Thrupp (2000) reported that involvement of farmers as partners in research and development increases the rate of adoption.

Thrupp (1989) suggested that innovative, participatory research and development activities can empower rural people to develop confidence and pride in their own knowledge systems and technological capabilities. Empowerment through effective participation has helped marginalized people to develop a sense of solidarity and collective political bargaining power (Thrupp 1988). Other studies have noted that farmers are good at conserving technologies that work (Andrews 1992). A plant breeding project of International Center for Tropical Agriculture (CIAT) in Rwanda demonstrated a successful case study of collaboration between scientist and women farmers in breeding new varieties of beans that suited local people's needs. Thrupp (2000) found that varieties that were selected and tested by women performed better than the scientists' own local mixtures.

Ethnobotany of Stinging Nettle

Plants in the family Urticaceae have been used as medicine, pesticide and as foliar fertilizers for many years. Stinging nettle (*Urtica dioca L.)* although wild, is occasionally cultivated for medicinal purposes. Nettle's leaves have been found to contain histamine, acetylcholine (Emmelin and Feldberg 1947), formic acid, tannins, 5-hydroxytrypatamine (Collier and Chesher 1956), vitamins A , C and D; mineral salts, calcium, potassium, silicon, iron, manganese and sulfur (Wheeler 2002). Stinging nettle's leaves contains 21-23 % of crude protein and 9-21% of crude fiber. Pharmacological studies by Chaurasia and Wichtl (1987) reported that sterols and steryl glycosides are other chemical compounds found in leaf extract of *U. dioca*. Stinging nettle leaf contains flavonoids that help to maintain the healthy levels of histamine (Hill 1998).

Medicinal Value

Because of the above constituents, members of Urticaceae family are known to have many therapeutic applications especially in internal hemorrhoids, as a laxative and in dermatological problems including eczema. *Urtica dioca* leaf powder is used as a snuff to stop nose bleeds and has been shown to lower the blood sugar levels as well as lowering the blood pressure. In Europe, nettle roots have been used in hair products to promote hair growth, treat eczema and control dandruff (Wheeler 2002). Fresh branches are applied externally to control rheumatism through the stinging hairs (Pollard and Brings 1984). Nettles are used medicinally in many countries because of their diuretic, stringent and galactologic properties (Chaurasia and Wichtl 1987; Hill 1998). Nettle has widely been used in Europe for treatment of diseases and disorders due to its medicinal properties (Wheeler 2002). Specifically, nettle has been used widely for treatment of gout and weight loss in Europe. Healers in several traditions have successfully used stinging nettle branches to strike the arms or legs of paralyzed patients in order to activate their muscles (Hill 1998). Sahelian (1998) reported that several studies in Germany indicate that root extracts of stinging nettle have been used for symptomatic relief of urinary difficulties associated with early stages of benign prostrate hyperplasia (BPH). Additional studies by Schoettner et al. (1997) indicated that the presence of lignin mainly neo-olivil in the roots of *Urtica dioca* is responsible for the positive effect in control of BPH. Nettle leaf extract have been found to promote the healthy modulation of prostaglandins, leukotrienes and cytokines which are key components associated with immune function of the body. Clinical studies by Chrubasik et al. (1997) in Germany showed that stinging nettle used as stewed herb may enhance the anti-rheumatic effectiveness in acute arthritis.

In Europe, the long and fibrous stem of nettles has been used for weaving, cloth making, cordage and even paper. Native Americans used nettle fibers for embroidery, fish nets and other crafts (Hill 1998).

Use of Stinging Nettle as a Pesticide

Kraus and Spiteller (1991) found *Urtica dioca* to be effective as aphid repellents. Bozsik (1996) carried out studies on aphicidal efficacy of different stinging nettle extracts fermented on plum (*Prunus domestica* L.), red currant (*Ribes rubrum* L.) and (*Spiraea vanhouttei* L.) and found it to reduce infestation, although not significantly. Wheeler (2002) reported that the water extracts of stinging nettle have successfully been used to control angular leaf spot of cucumber by 32-66%. Specific studies have demonstrated that *U. dioca* have antifungal properties (Yongabi et al. 2000). Similar studies by Soliman et al. (2005) reported that stinging nettle extracts exhibited some effects on fungi, particularly *Penicillin commune* and *Rhodotonia rubra.* Other studies compared the insecticidal activity of stinging nettle lectins with rice lectins showed that with increase of *U. dioca* lectin dose, there was a significant increase in cowpea weevil mortality (Huesing et al. 1991).

Studies in Poland showed that water extracts of *Urtica dioca* was more active as a natural pesticide against aphids than synthetic pesticides (Achremowicz and Ciez 1992). Organic solvent's extract of stinging nettle leaves depressed the growth of staphylococci bacteria (Lezhneva et al. 1986). Other studies in Germany reported that the presence of weed species of stinging nettle (*Urtica dioca)* in lettuce cultures led to a reduction in the aphid infestation on lettuce when compared to wormwood (*Artemisia vulgaris* L.*)* and tansy (*Tanacetum vulgare* L.) plant extracts (Sengonga et al. 2002). More studies in Europe have identified stinging nettle as one of the natural plant extracts used for crop protection (Wheeler 2002).

Foliar Fertilizer

Nettle tea has been used as foliar fertilizers in horticulture for a long time. Studies carried out in Germany noted that plants treated with nettle water had positive effects such as increased plant growth, dark green leaves and better resistance against pests and diseases. Studies by Peterson and Jensen (1985) reported that nettle water contained a high amount of nitrogen, mainly as ammonium compound. Peterson and Jensen (1987) reported that water extracts of *U. dioca* had growth stimulating effect on plants. Their study also confirmed that plants treated with nettle water (an aqueous extract of stinging nettle) had 20% higher shoot fresh weight and 15 % higher nitrogen contents than plants that were given a nutrient solution with about the same mineral composition (Peterson and Jensen 1986).

CHAPTER 3: COMMUNITY DEVELOPMENT

Introduction

Most farmers in developing countries particularly Sub-Saharan Africa are resource poor in terms of access to natural resources, credit information and external inputs (FAO 2000). The causes of rural poverty include: low agricultural productivity which is exacerbated by land degradation and insecure land tenure, unemployment and low wages, difficulty in accessing financial support for self-employment, unequal food distribution (Thrupp 2000). Inadequate infrastructure, HIV/AIDS, high costs of health and education are other additional causes of rural poverty (FAO 2005).

Agriculture is the backbone of Kenyan's economy. It provides employment to millions of Kenyans either directly or indirectly and earns foreign exchange for the nation. Currently, 85% of the Kenyan population depends on subsistence farming (KFSSG 2005). Therefore, the national food security issue depends on smallholder farmers who spend nearly 100% of their time in the rural areas on small portions of land ranging between 3-5 acres. Kenyan's economic growth, previously at an average minus 2% per annum, now stands at 5.8 % per annum. This is against a population growth of 2.8 % per annum. By the end of 2005, 56% of Kenyans lived under poverty line. This is a drastic rise from 45% in 1995. The current increase in population growth rate in Kenya has led to increasing pressure on natural resources, a widening income gap and rising poverty levels that erode gains in education, health, food security, employment and incomes (KFSSG 2005). Many households in Kenya experience both transitory and chronic food insecurity. The causes are many and include erratic weather conditions, rapid population growth, high food prices, changed agricultural practices, poor food distribution and marketing systems, low purchasing power, inadequate research and extension support to indigenous food crops, lack of appropriate technology to enhance food production and processing and lack of sustainable mechanisms to deal with emergency food situation (Hamilton 1997).

Since the beginning of agriculture, farmers in Kenya have developed a very wide range of farming practices that contribute either directly or indirectly to pest management. Examples include: sanitation, weeding, rotation, multiple cropping, zero tillage, fire, flooding and natural pesticides (Lenne' 2000).

During the summer of 2006, two consultative meetings were held with Kamweti stinging nettle and beekeeping group in the southern part of Mount Kenya. During the two meetings, discussions on community development projects, micro-enterprise development, setting up priorities, community needs assessment, gap analysis and actions plans were carried out through deliberations and focused group discussions. The group was interested in micro-enterprise development and learning sustainable agriculture and organic farming skills. The farmers prioritized stinging nettle pesticide as the product that they needed to develop and market. Though the farmers had skills to process the pesticide and utilize it in their own farming systems, they raised concerns on scientific validation of why it works and whether it is proven to be a pesticide or a bio-fertilizer. The farmers had tried several attempts to market the products locally. Their present market outlet existed within the Kamweti region. Most members utilized the nettle product to grow their own crops. The major challenge in marketing the product was due to delay in getting their trading license which is a requirement before they could sell it through the supermarkets and major retail shops. The trading license required a scientific validation that the pesticide works and there are no negative environmental impacts associated with its use.

The experimental investigation was aimed at addressing the scientific validation of farmers' practice on the utilization of stinging nettle as a biopesticide. Although *Urtica dioca L. (in* the family Urticaceae) is a widely distributed species in the world, the species that is most common around Mount Kenya is *Urtica diversifolia* L. (Figure 1; and Figure 2). The experiment in this research tested the efficacy of stinging nettle (*Urtica diversifolia)* on four commonly grown vegetables in Kenya (Collard green, Swiss chard, tomatoes and French beans) by comparing the fresh biomass yield, plant growth, pest damage levels, types of pest present and their abundance on the treated and control plots. Soil samples were also taken and analyzed for nitrogen, phosphorus, potassium and pH levels. Average temperature and rainfall amount was also recorded on a daily basis.

The applied concentration and frequency of pesticide treatment chosen was based on what farmers considered the best, based on their experiences. Scientific methodology was applied to set up the experimental design and analyze the data. The results of this study would be shared with farmers and the entire Kenyan Ministry of Agriculture staff as well as other collaborators working with farmers to increase food security. The information obtained would serve as a basis to determine policies on whether the stinging nettle pesticide should be sold in the market as a commercial product. The results are aimed at testing the claim that the naturally occurring pesticides have a prominent role in the development of future commercial pesticides not only for agricultural crop productivity but also for the safety of the environment and public health.

Figure 1: Urtica diversifolia plant growing naturally in the forest

Figure 2: Stinging nettle growing in the farmers' field

In addition to the scientific experiment, several interviews were conducted to have an in-depth understanding of why the farmers worked as a group, evaluate the benefits of working as a team, find out their personal experiences with the stinging nettle and their roles and responsibilities in the group. Several probing questions were asked to individual farmers at the household level. Observations on their common agricultural practices were also made during the transect walks. Six people outside of the Kamweti stinging nettle and beekeeping group were also interviewed to get comparative opinions on benefits of working together. In the following sections the participatory model used to encourage farmers' participation is highlighted, the description of the Kamweti group and the process used to involve farmers in identifying project, training needs assessment, results and discussion are described.

MATERIALS AND METHODS

Description of Kamweti Stinging Nettle and Beekeeping Group

The Kamweti farmer's group was formed in the year 2002 and was registered with the Ministry of Gender Sports, Culture and Social Services in 2003. The group comprises of 29 small holder farmers. The Kamweti group was formed with an objective of improving their livelihood through the processing and marketing of the stinging nettle and undertaking beekeeping project as an income generating activity. The average land size ranges from one quarter acre to three acres. The cropping system is quite diverse. All of the group members grow tea and coffee as cash crops while maize, beans and vegetables are predominantly grown as food crops. Food security and agro-income security are major issues in this region. The major causes of food and agro-income insecurity are illustrated in Figure 3.

Most of the farmers concentrate on farming tea instead of growing food crops. Ninety percent (90%) of the funds earned from the sale of tea is used to pay school fees for their children and to buy food from the local market. Though faced with the challenge of limited land, the farmers do not have adequate experience of intensive cultivation and integrating their farming enterprises according to principles of organic farming. The farmers keep non pasture raised dairy cows. The challenge has been getting enough pasture for their cows. Due to lack of skills in compost making most of the farmers take the fresh cow dung manure directly to their farms. This has negatively impacted their land by spreading diseases and decreasing soil fertility. The soil analysis results for all the soil samples collected from the group members' fields confirmed that their soils had very poor nitrogen and phosphorus levels.

The Kamweti region has rainfall patterns conducive to productive farming and most of the agricultural crops do very well except in the cold months of July and August when frost is common. Vegetables such as cabbage, Swiss chard, collard green and tomatoes are sold in the local outlets of Kamweti and Karumandi local product market centers that are within two kilometers from the village. Marketing of their farm produce has been a major challenge due to exploitation by brokers and middle men. Except for tea and coffee that have formal market structures, all other food crops have no organized market channels. Occasionally, the seed companies and agrochemical companies have been giving farmers French bean seeds to grow which provide them with the potential market, but this has led to over exploitation of farmers. Most farmers have therefore ended up either incurring loss for their produce or getting lower prices than what is offered in the market.

Ice Breaking and General Introduction

Upon arrival in the Kamweti farmers training center where most of the training workshops took place, general introductions were performed by Professor Kariuki from Egerton University and John Sheffy, the GEM Outreach Program Manager for the Sustainable Agriculture and Agro-forestry Program of the Global Environmental Management Education Center (GEM) , University of Wisconsin Stevens Point (UWSP). The farmers introduced themselves by their name, role and responsibility in the group and name of the region where they came from. Professor Kariuki introduced the team from the University of Wisconsin- Stevens Point and the Egerton students to the farmers. John Sheffy introduced the students from the Kenya Institute of Organic Farming (KIOF) and then he explained the collaborative GEM activities with farmers in different regions of the world.

Participatory Training Needs Assessment

To identify farmers training needs a training needs assessment workshop was carried out. Figure 3 illustrates some of the broad issues that were discussed as the major causes of food and agro-income insecurity. The farmers were divided into three groups and facilitated discussions were conducted to determine what skills the farmers thought they needed in order to improve their farming activities and marketing of their farm products including nettle product (Figure 4).

Each student intern was assigned a group to facilitate brainstorming sessions on training needs. After a thirty-minute discussion session each group team presented its outcomes for sharing.

The sessions identified the following training need priorities:

1. Natural soil fertility management: Intercropping and crop rotation.

2. Introduction to composting, types of compost (trench composting, vegetation compost, boma compost and basket compost), liquid manures and plant teas.

3. Building improved cooking stoves (jikos).

4. General record keeping of all farm activities and cost benefit analysis per enterprise.

4. Gender roles and responsibilities in the household.

5. Marketing techniques and potential options.

6. Other botanical pesticides.

7. Beekeeping.

8. Intensive gardening techniques (square meter gardening, 5-9 seed hole, double-dug beds, deep-dug beds, indigenous vegetables (moving their focus from exotic vegetable to indigenous vegetables).

9. Efficient use of labor.

10. Pests and disease infestation.

11. Food processing and marketing.

12. Soil analysis for major macro-nutrients.

The summaries of the above training needs are illustrated in Figure 4. To accomplish the above training within three months, theory and practical training workshops were scheduled two days per week. To ease the implementation of the trained activities at the farm level, the farmers were divided into four groups. In addition one Kenyan student intern was assigned to each group to serve as an extension specialist for the farmers (See Appendix 1 for list of group members and students assigned). Each group of farmers also chose a group leader to coordinate all the training activities within their group.

The major causes of food and agro-income insecurity identified by the group are illustrated in Figure 3. High population and subdivision of land size into smaller unit was the major cause of poverty in Kamweti region. Farmers have a cultural obligation of passing over their land to all their sons. Inadequate farm input and lack of credit facilities has limited the farmers from expanding their farming business. The farmers also expressed their concerns on the cost of the chemical pesticides and the pest damage levels coupled with the problems of soil infertility as other additional causes of food insecurity. The above-stated problems form the basis of why Kamweti farmers group came into existence. The Kamweti farmers group was initiated to address the issue of increasing their food security situation through reducing pest damage levels by use of natural pesticide and developing income-generating projects to increase their agro-income for sustainable livelihoods.

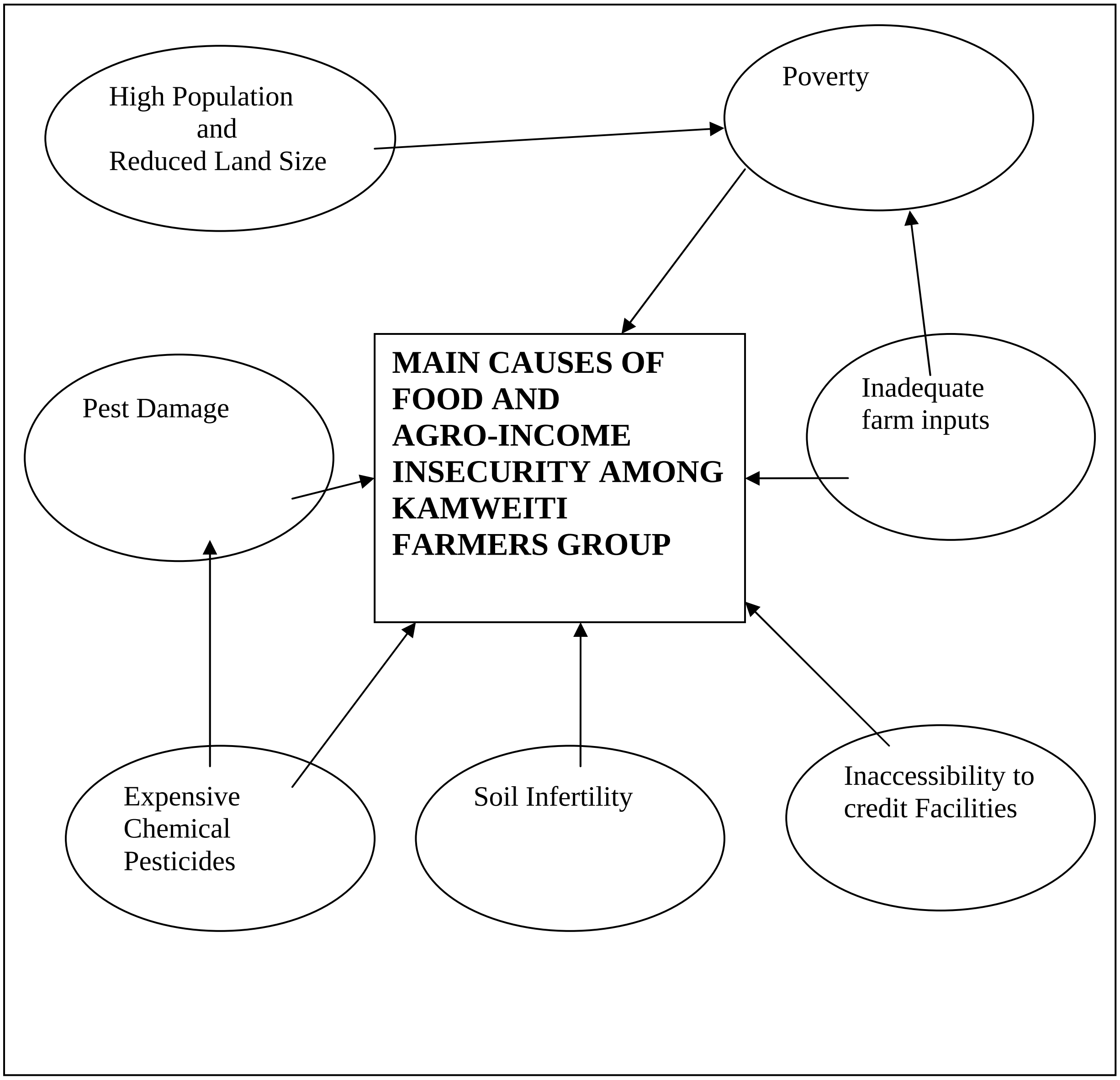

Figure 3: Causes of food and agro-income insecurity among Kamweti smallholder farmers group.

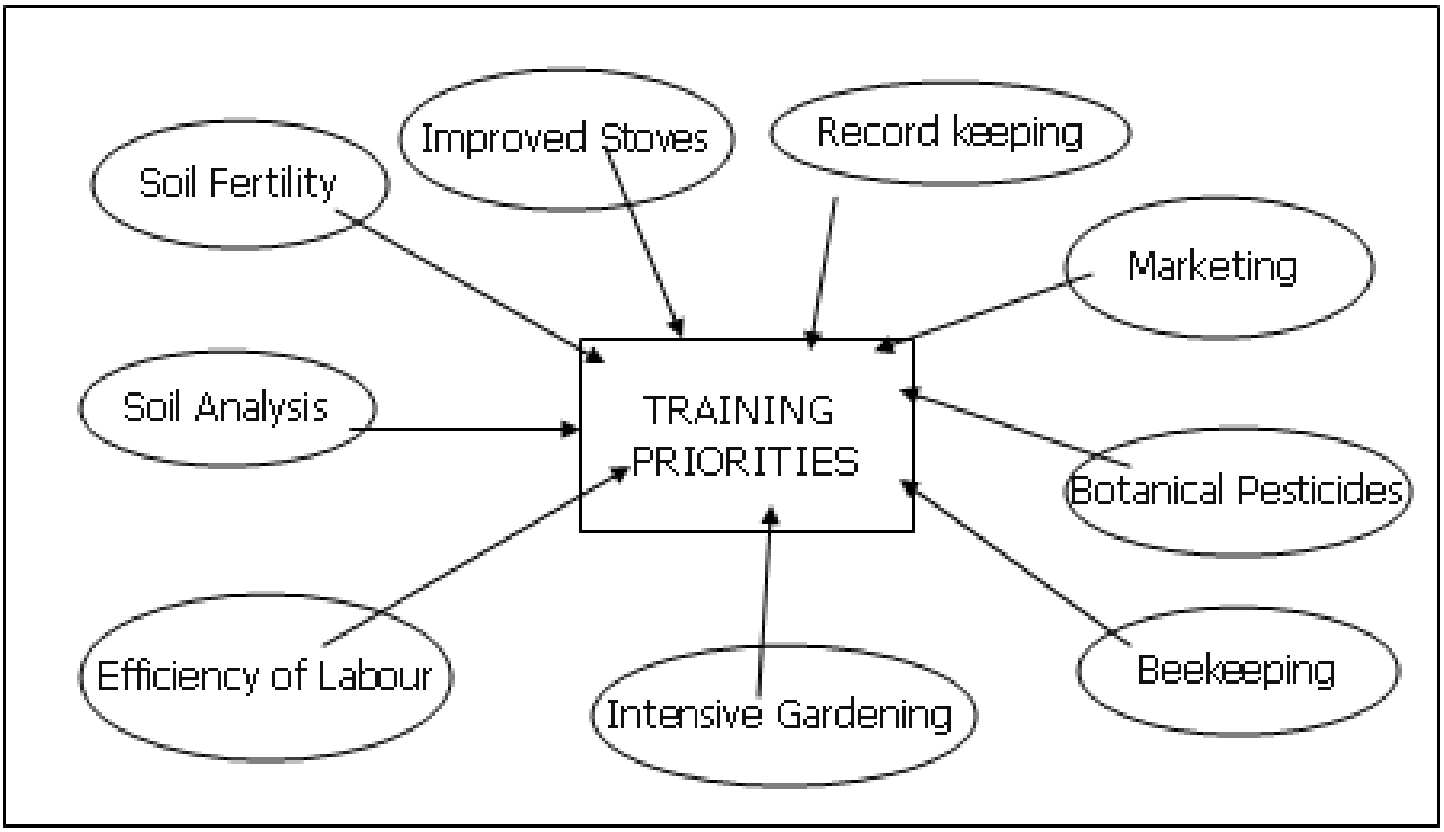

Figure 4: Summary of training priorities identified during the two day consultative workshop.

Training Achieved by Date, Topic and Attendance.

A total of twenty -three training workshops were carried out and subsequent meetings with farmers were completed as shown in Table 1 below.

Table 1: Schedule of trainings achieved by date, activity, and attendance.

Date	Activity	Attendance		
		Men	Women	Total
6/8/06	General introductions, history of the group and background of the stinging nettle project	15	11	26
6/9/06	-Group project identification and setting up of priorities -Needs assessment and community action plans	15	11	26
6/10/06	-Income generating projects for development groups	10	4	14
6/27/06	-Demonstration of vegetation type of compost and preparation of 5-9 Seed hole	3	2	5
6/28/06	-Introduction to organic farming, principles of organic farming.	3	2	5
6/28/06	-Demonstration on vegetation compost	2	1	3
6/30/06	-Practical on preparation of 5-9 seed hole. -Making of basket type of compost	4	2	6
7/3/06	-Training on group dynamics and leadership skills.	15	11	26
7/4/06	-Theory of composting -Practical on portable gardens	5	2	7
7/4/06	-Making 5-9 Seed hole -Preparation of vegetation compost	5	2	7
7/6/06	-Introduction to beekeeping, history of bee keeping in Kenya, traditional practices on bee keeping, importance and the economic value of Beekeeping and bee colony.	12	9	21
7/11/06	-Beekeeping- bee botany, bee colony management.	13	3	26
7-9 July 2006	-Collecting of the soil samples and demonstration of sampling techniques to farmers in their farms	15	11	26
7/8/06	Meeting with farmers, professor Kariuki and all the student interns to review the progress of the project and missing gaps.	12	9	21

7/13/06	Bee products, bee behavior, apiary setting, honey processing and marketing	13	3	26
7/18/06	-Honey colony management, colony division	10	3	13
8/1/06	-Introduction to Bosnia -Cooking Tomato soap (Theory)	10	3	13
8/3/06	-Waste management -Herbs and spices -Cooking tomato soup (Practical)	11	5	16
8/3/06	-Waste management	9	4	13
8/10/06	-Composting- Kitchen Waste other materials for composting. -Record keeping (2 Sessions)	10	4	14
8/15/06	-Soil fertility management (Boma compost, liquid manure, animal dung manure, urine and plant teas	9	6	15
8/15/06	-Soil Nutrients- Macro and micro nutrients -Soil samples analysis reports and recommendations for pH, N, P and K	15	11	26
8/17/06	-Other botanical pesticides -Preliminary research results -Record keeping Evaluation of the training program	15	13	28

Soil Analysis

A total of 28 soil samples were tested for pH, nitrogen, phosphorus and potassium. From the soil analysis results 90% of the soil samples resulted in low nitrogen levels, while over 50% of the analyzed samples resulted to slightly acidic, low phosphorus levels and high potassium levels (Figure 5 and Figure 6).

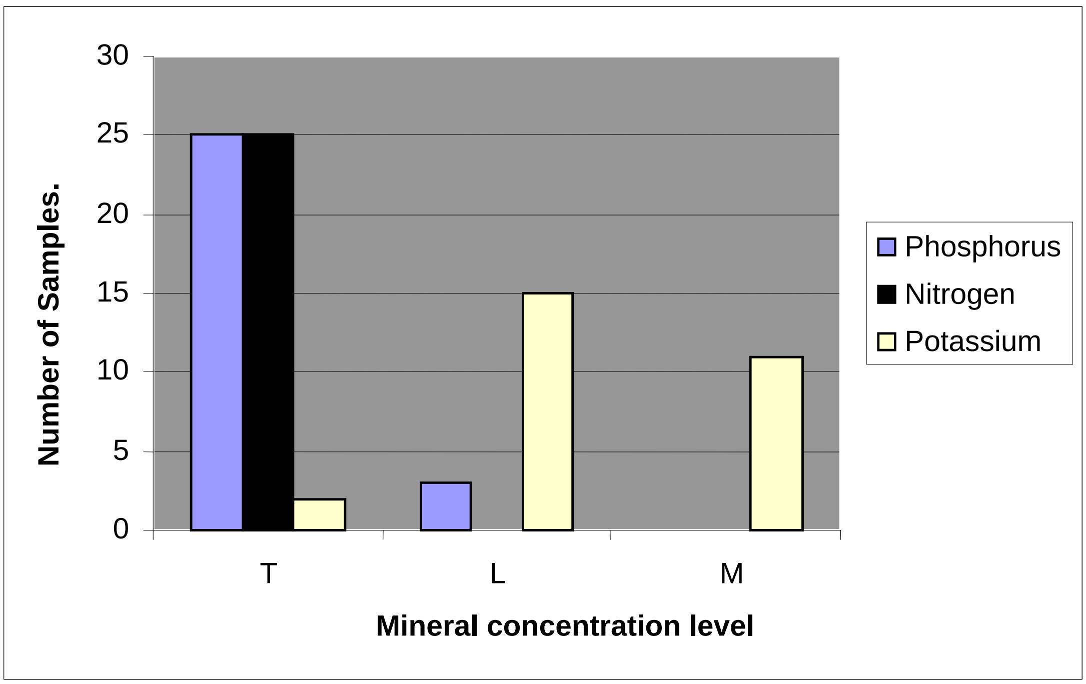

Figure 5: Soil analysis results showing the mineral concentration level on the X- axis and number of samples on the Y-axis.

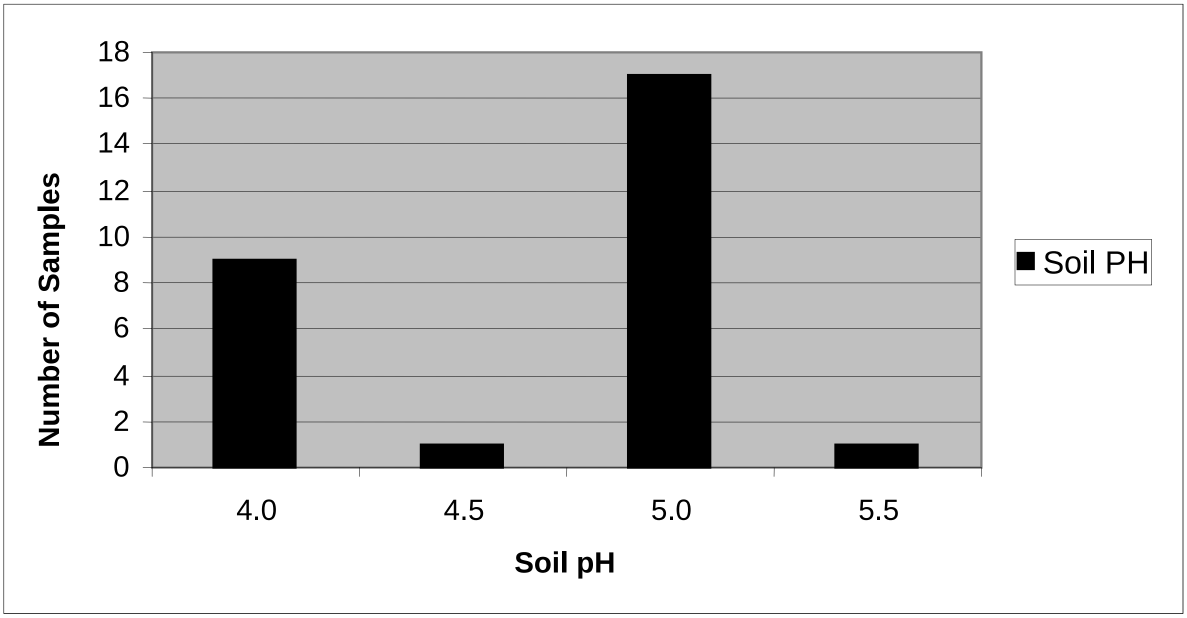

Figure 6: Soil analysis results showing the soil PH level on the X- axis and number of samples on the Y-axis.

Group Project Identification and Setting Up of Research Priorities.

To identify the group project and set up research priorities, the farmers were grouped into four discussion groups and each group deliberated on their current sources of income and expenditures using a cash flow analysis method. This process was facilitated with the help of Egerton University and KIOF intern students. This was a very informative discussion and it engaged every farmer in the group. Each group chose one farmer to present their deliberations to the rest of the members. The presentation layout was illustrated in the form of a tree where sources of income formed the roots and the branches formed the expenditure. All four groups identified tea and coffee as their major source of income and horticultural crops like tomatoes, cabbage, collard green, French beans and Swiss chard as other sources of income. The farmers went through another exercise to identify the group objective, identify the products and the markets potential based on their earlier discussions. This gave them the skills to plan for an enterprise by addressing areas of development such as processing, marketing and estimating cost.

Through deliberations and focused group discussions, the farmers prioritized stinging nettle pesticide as the product that they needed to develop and market. Though the farmers had skills to process the pesticide and utilize it in their own farming systems, they raised concerns on scientific validation of why it works and whether it is proven to be a pesticide or a bio-fertilizer. The farmers had tried several attempts to market the products locally. Their present market outlet existed within the Kamweti region. Most members utilize the nettle product to grow their own crops. The major challenge in marketing the product was due to delay in obtaining their trading license which is a requirement before they could sell it through the supermarkets and major retail shops. The trading license requires a scientific validation that the pesticide works and there are no negative environmental impacts associated with its use.

Two brainstorming workshop sessions were conducted to address the solutions to the trading license requirement. Through a consensus, it was agreed that there was a need to set up an experiment to test the efficacy of the pesticide. The farmers also needed to know the scientific explanation of why the nettle product works as a pesticide. This necessitated the need to set up the experimental study that was aimed at addressing the scientific validation of farmers practice on utilization of stinging nettle as a biopesticide. In order to determine the efficacy of *U. diversifolia*, a field experiment was set up using the treatment protocol that the farmers had already tested though trial and error. The applied concentration and frequency of pesticide treatment chosen was based on what farmers considered optimal based on their experiences. Scientific methodology was applied to set up the experimental design and analyze the data as described in Chapter 4.

CHAPTER 4: SCIENTIFIC VALIDATION OF STINGING NETTLE AS A BIOPESTICIDE

Introduction

A large number of plant species contain natural pesticide properties that humans have used since the beginning of agriculture. Botanical extracts are those extracts derived from plants which are used to control or modify the effects of organisms considered injurious to humans and plants (Tvedten 2007). Plants exhibit a defense mechanism based on chemical and secondary metabolites. These chemicals have evolved in order to protect the plant itself from attack by insects and other herbivores animals (Verkerk 1998). Most botanical extracts are comprised of a large mixture of compounds which mostly are either alkaloid or phenolic in nature (Tvedten 2007). Botanical extracts are used by farmers both for preventive pest management as well as for curative purposes, when pest outbreak is already present. A good example is neem plant which has been shown to contain as many as sixty (60) active ingredients), the most important of which is azendirachtin (Copping 1998). Damage by herbivores particularly by arthropods such as insects and mites can be reduced to acceptable levels when effective biopesticide obtained from botanical extracts are applied to susceptible plants. Use of natural plants products in agro-ecosystems is emerging as one of the prime means to protect crop pest (Van 1992).

According to Tvedten (2007), botanical pesticides exert their effect as pest management in great diversity of ways; they may be insecticide (contact and or stomach poisons), antifeedants, dehydrants, sterilants or behavior modifiers (including repellency, altered locomotion, mate or host location). Some botanical pesticides are also thought to exert their effect in pest and disease management by enhancing the vigor, resistance or compensation ability of the plant under attack (Roak 1942). Since botanical products have complex and often multiple modes of action, the risk of resistance development as a result of use of natural extracts is almost negligible.

The specific objective of this study is to investigate the efficacy of *U. diversifolia* (stinging nettle) as a biopesticide in collard green, tomato, Swiss chard and French beans.

MATERIALS AND METHODS

Location and Relief

The experimental trials were conducted during the summer of 2006 at Kamweti location in Kirinyaga district of the Central Province of Kenya. Kamweti is located approximately latitude 0º 20'S to 0º 22' S and longitude 30º 25'E to 37 º 30'E. The area is located on the southern slopes of Mount Kenya (Figure 7). Three quarters of the area is surrounded by Nyayo Tea Zone (Kenya tea zone and forest conservation) forming a buffer zone between the forest and farmers field. The cultivated area is an undulating high region rising gradually northwards towards Mount Kenya whose highest point reaches 5836 meters above sea level. The average altitude of the cultivated area is 2194 meters above sea level. The area is dissected by several rivers and streams; the main ones being the Kamweti River and the Kavute River, all of which are tributaries of the Thiba River. The later drains into the Tana River. These are permanent rivers which supply water not only in this region but form the main sources of irrigation water in the Mwea Rice Irrigation Scheme (MOA 1988).

Climate

The Kamweti area has a cool, moist climate. The mean temperatures range from 16.6 degrees Celsius in the coldest month and 20.1 degrees Celsius in the warmest month. The rainfall is bimodal with two peaks, one from March to May (long rains) and the other from October to December (short rains). The annual rainfall ranges between 800 mm to 2150 mm (MOA 2000).

Study Site

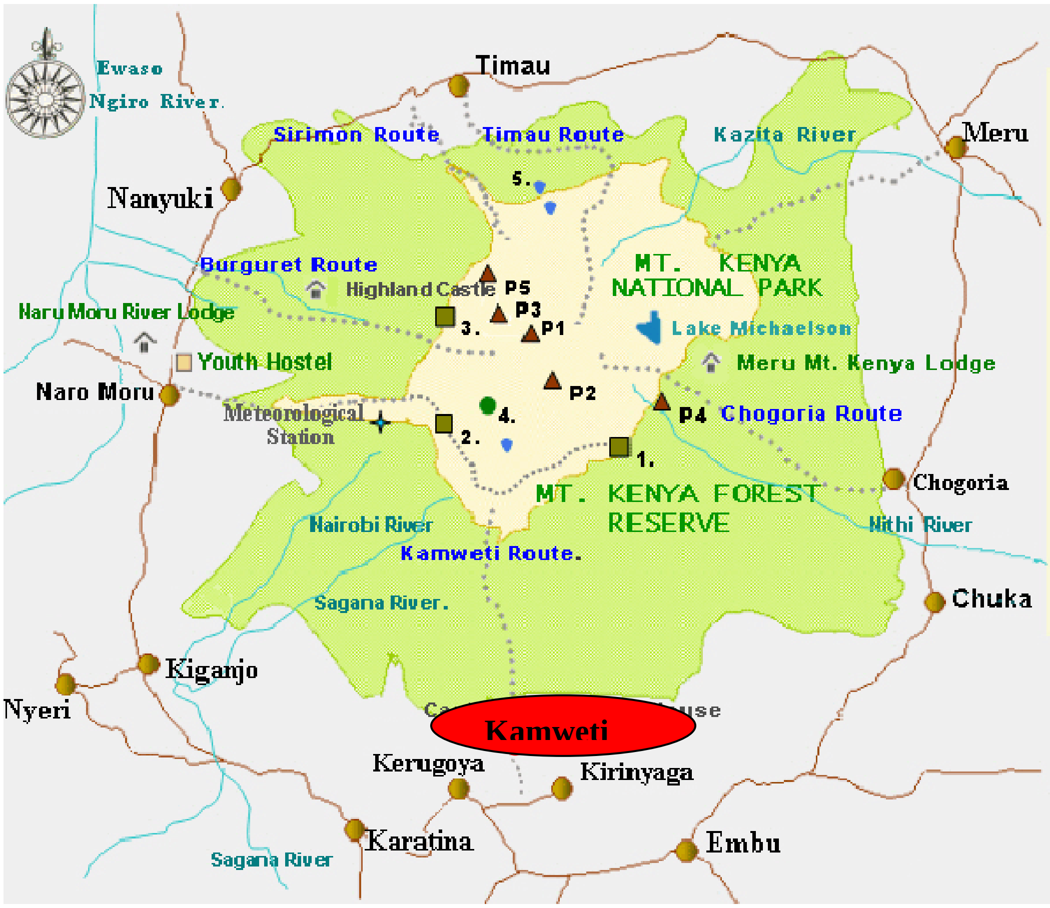

Figure 7: Map of Mount Kenya forest reserve and neighboring communities showing Kamweti

Geology and Soils

Kamweti area is characterized by tertiary recent volcanic rocks. The soils are generally strong brown loams derived from volcanic ash and occur in dissected land. In some areas soils are reddish and also have smeary consistence. Brown loamy soils absorb much water and contain (5 to 20%) organic matter. The soils are fertile and well drained with a good permeability and a stable soil structure.

Vegetation

Most of the Kamweti area has been cleared for cultivation and the natural vegetation is only restricted to the forest. The forest consists of both natural and exotic species. The most predominant exotic tree species include *Eucalyptus saligna* Attims and *Cupressus lusitanica* L. Examples of indigenous tree species include *Rapanea melanophloeos* (L), *Cordia abyssinica* R.Br, *Olea europea var. Africana* (Mill), *Ficus thoningii* Bl., *Podocarpus gracilior* Pilger and *Myrianthus holstii* Engl. Some of the common shrubs around Mount Kenya are *Rhus vulgaris* Meikle, *Vernonia auriculifera* Hiern, *Geranium arabicum* Forsk, *Ranunculus oreophytus* Del., (Dr Samuel Kariuki, Egerton University, personal comm. June 2006). *Urtica diversifolia* is one of the common understorey naturally growing herb in the forest. *Urtica diversifolia* is found as weed species in farmers' coffee or tea plantations and grows to a height of 30-150cm tall.

Processing of Stinging Nettle (*Urtica diversifolia*) Pesticide by Kamweti Group.

Stinging nettle (*Urtica diversifolia*) seeds were collected from the forest and broadcasted on farmers' field. The germination took place three weeks after planting. The stinging nettle plant takes five to six months before flowering. The leaves were cut with scissors to separate the stem from the leaves during harvesting. The leaves were dried by placing them in a cool dry house. Drying the leaves under shade facilitated removal of the moisture content while maintaining all the other components and nutrients in the leaves. After drying, the leaves were ground into fine powder and stored in air tight packing plastic bags until use.

Dilution and Concentration.

A concentration of the pesticide was prepared by mixing five kilograms of *Urtica diversifolia* powder with 50 litres of warm water and fermented for seven days. Wire mesh sieves were used to remove course leaf materials from the solution. In order to get a clearer liquid, a muslin cloth was used as a sieve to remove the small suspended particles. This solution was then diluted with five litres of water. Plants were sprayed with the solution once a week. Previously, farmers had carried out a field research in collaboration with Egerton University on testing different concentrations at different frequencies on kale, tomatoes and tree tomatoes. The farmers confirmed that spraying once a week was the most effective. The pesticide was diluted at 1:3, 1:5, 1:7 and 1:10 to test the best concentration. The results indicated that the ration of 1 to 5 concentrations had the best results (Dr. Samuel Kariuki, Egerton University, personal comm. June 2006). To validate the farmers' practices in this experiment, the plots were sprayed at a frequency of once a week using the same concentration of fermented leaf powder to water ratios of 1 to 5.

Experimental Design

The efficacy of the stinging nettle pesticide was tested by comparing the fresh biomass yield, plant growth, pest damage levels, types of pest present and their abundance on the sprayed and unsprayed plots. Soil samples were also taken and analyzed for nitrogen, phosphorus, potassium and pH levels. Average temperature and rainfall amount were also recorded on a daily basis. Two treatments were arranged in a Generalized Randomized Block Design (GRBD) with four replications per treatment (Little and Hills 1978; Emeasor and Ezueh 1997; Gomez and Gomez 1984) for tomato, French beans, collard green and Swiss chard. Each replicate plot was 2.m X 2 m in size (6.8ft X 6.8ft) with 0.61m (2 ft) wide pathways in between each replicate plot. The treatment was assigned randomly to all the plots in the four blocks. The two treatments comprised of pesticide application and control was sprayed with distilled water. The concentration of pesticide to water solution was in the ratio of 1 to 5 respectively. The experimental layout is illustrated in Figure 8.

P1 Control	**P2** Control	**P3** Pesticide	**P4** Pesticide
P7 Pesticide	**P7** Control	**P6** Control	**P5** Pesticide

Tomato

P1 Control	P2 Pesticide	P3 Control	P4 Control
P8 Control	P7 Pesticide	P6 Pesticide	P5 Pesticide

Collard Green

P1 Pesticide	**P2** Control	**P3** Pesticide	**P4** pesticide
P8 Control	**P7** Control	**P6** Pesticide	**P5** Control

Swiss chard

P1 Pesticide	**P2** Pesticide	**P3** Control	**P4** Control
P8 Control	**P7** Pesticide	**P6** Pesticide	**P5** Control

French beans

Figure 8: Experimental layout to test the stinging nettle efficacy as a biopesticide on tomato, Collard green, Swiss chard and French beans.

Land Preparation and Planting

The experimental plots were prepared before planting. The four blocks were leveled by loosening the soil and using a rake to collect the course materials. Soil samples were taken for analysis. Two wheelbarrows of compost were applied per plot and mixed with the soil before planting. French bean seeds were planted on June 19, 2006 while tomatoes, collard green and Swiss chard seedlings were transplanted on June 20, 2006. The percentage of French bean seeds that germinated at eight days after planting was determined. Tomato (*Lycopersicon esculentum* cv. Money maker) seedlings were transplanted at a spacing of 60 cm X 45 cm (2 ft X 1.5 ft), while French beans, variety Julia seeds were planted at spacing of 30 cm X 15 cm (1 ft X 0.5 ft), Collard Green (*Brassica oleraceae* L. var. acephala cv. Georgia seedlings were transplanted at spacing 45 cm X 45 cm (1.5 ft X 1.5 ft) while Swiss chard (*Beta vulgaris* var. cicla cv. Fordhook Giant seedlings were transplanted at spacing 45 cm X 45 cm (1.5ft X 1.5 ft). The experimental plots were manually weeded. The first weeding took place three weeks after planting while the second weeding took place three weeks after the first weeding. Watering of the crops was done twice per day (morning and evening) except during the rainy days. Spraying with the stinging nettle pesticide was carried out from the 26th of June on weekly basis up to 14th August 2006.

Data Collection.

Observations on pest infestation and disease severity commenced from 27, June 2006 and data was collected on a weekly basis until 15th August 2006. Monitoring growth rate was done by measuring the height of the plant on a weekly basis. Collard green and Swiss chard were harvested on 16, August 2006 and the fresh biomass weights per plot were recorded. All the sampled plants for pest damage infestation monitoring, and height measurement were picked at random from the inner rows based on the recommendations of Gomez and Gomez (1984), Dythan (1999) and Little and Hills (1978) . Plants were scored from 0 to 4 for insect damage (0 - Indicating no damage; 1-indicating damage from 1- 20%; 2 indicating damage from 21- 50 % and 4- Indicating over 50% plant damage) based on the recommendations of National Agricultural Pesticide Impact Assessment Program (NAPIAP) as described by Dillard et al. (1997).

Analysis

Pest damage proportions, growth rate and biomass yield data was analyzed by analysis of variance (ANOVA) for GRBD and Tukey's Studentized Range (HSD) test was applied to separate means at 0.05 significant level. Also the 95% confidence limits and standard errors were calculated for each treatment mean. Daily temperature and rainfall amount were also recorded on a daily basis.

RESULTS

Fresh Biomass Weight

The mean fresh biomass weight of the pesticide treated plots was not significantly different from the control plots P > 0.05 (Table 2). The two way ANOVA confirmed that the pesticide treatment had no significant effect on the total fresh biomass weight of Collard green and Swiss chard (Figure 9). Based on Tukey's HSD test at 0.05 level of significance, the mean biomass yield was numerically higher for the plots that were treated with pesticide than the control plots though not significantly different (P > 0.05) as illustrated in Figure 10. Tomato plants dried during the eighth week due to tomato blight and therefore the fresh biomass weight received a score of zero during the analysis stage. The French bean seeds had less than 50% germination therefore no data was collected for French bean plots.

Table 2: Results of two-way ANOVA examining the effect of stinging nettle pesticide on collard green, Swiss chard and Tomato biomass yield. This table presents the source of variation, degrees of freedom (d.f), Mean squares (MS), F-Value and P-values.

Source of Variation	df	Mean square	F-Value	P-Value
Species	2	2.605	24.59	<.0001
Treatment	1	0.004	0.04	0.8529
Treatment* Species	2	0.009	0.08	0.9211

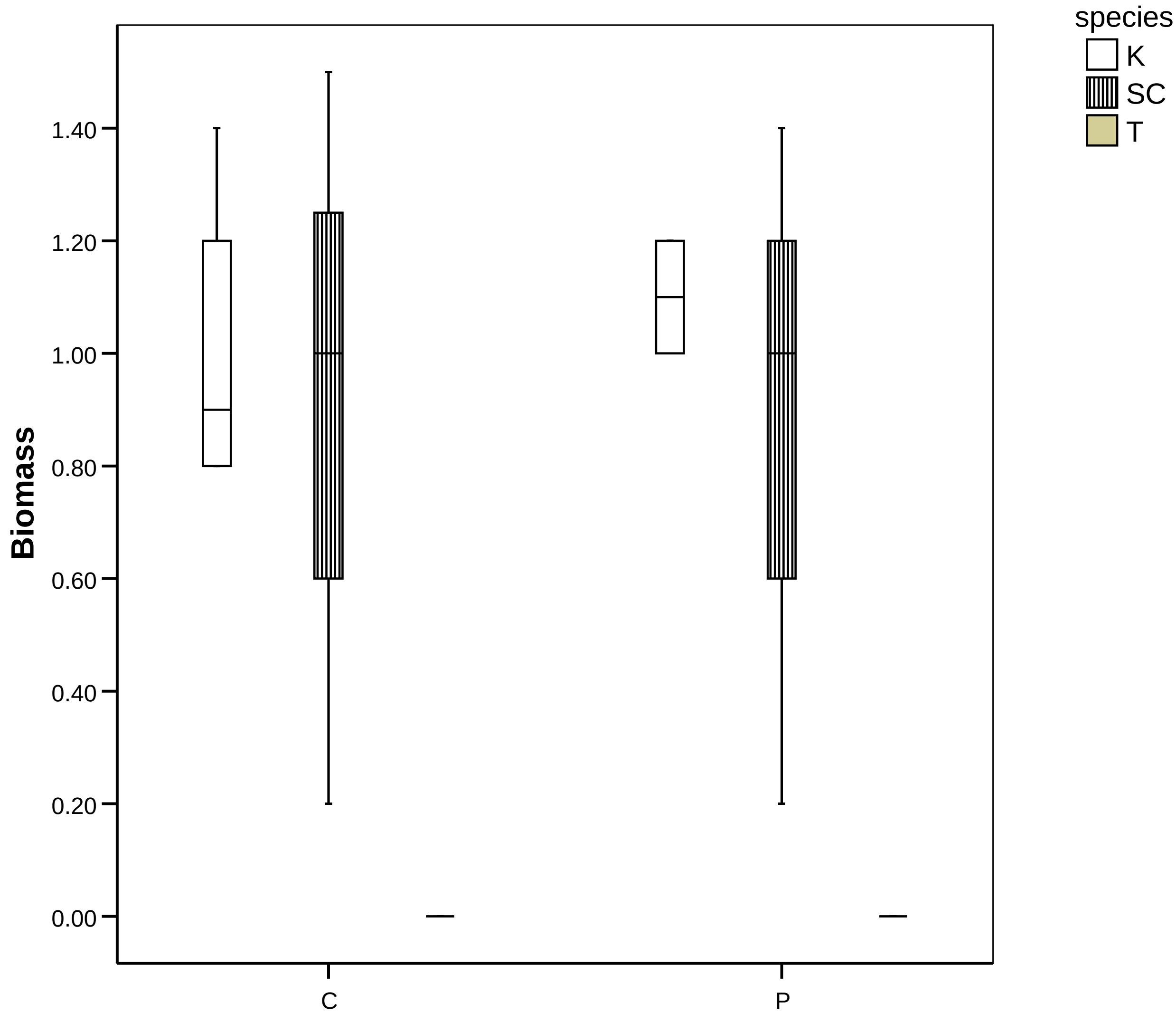

Figure 9: Effects of *U. diversifolia* pesticide on Fresh Biomass Yield (kg) of Collard Green (K), Swiss chard (SC) and Tomato (T) harvested at the age of nine weeks compared to control treatment. Error bars represents 95% confidence interval.

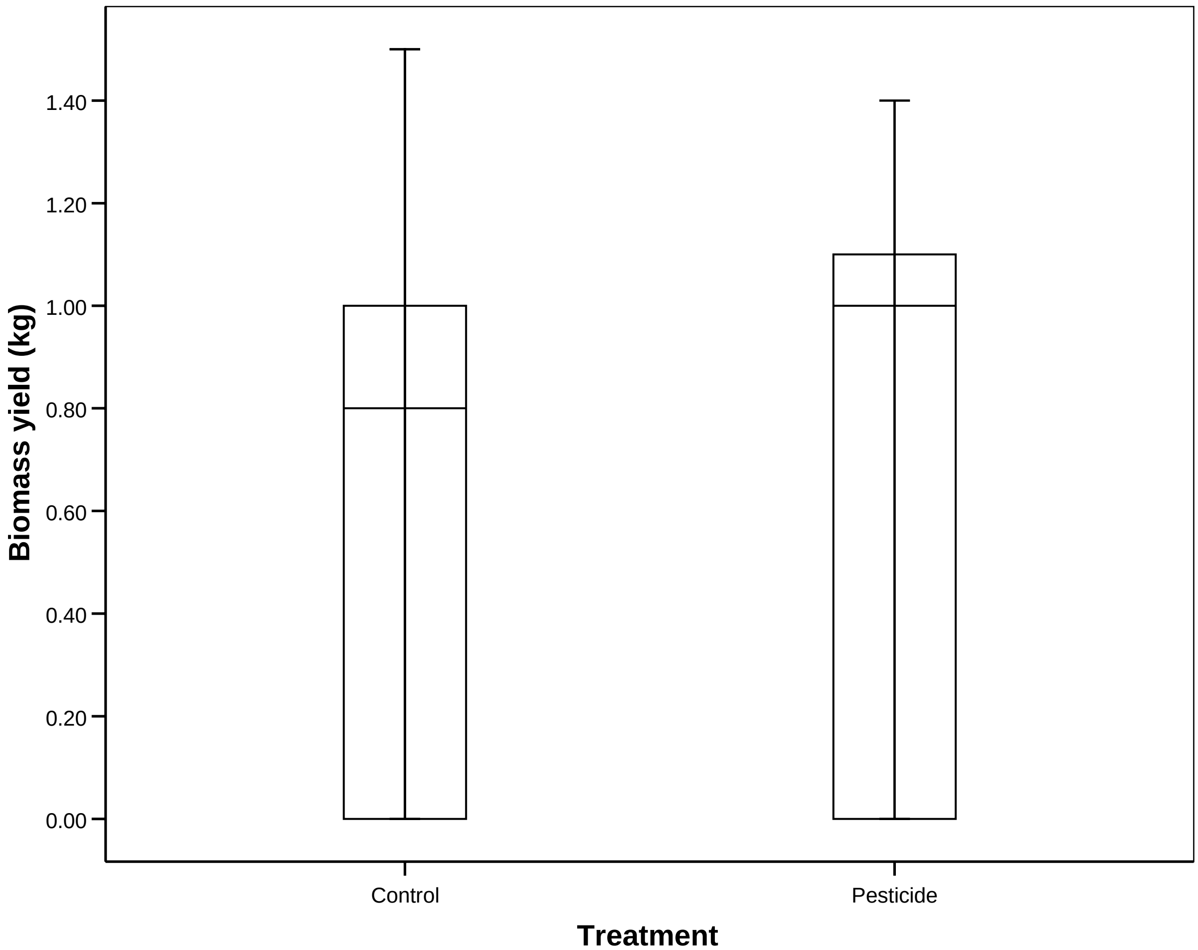

Figure 10: Effects of *U. diversifolia* pesticide on Fresh Biomass Yield (kg) harvested at the age of nine weeks compared to control treatment. Error bars represents 95% confidence interval.

Pest Abundance

All the arthropod species were pooled together and analyzed, but there were no significant differences between the control and pesticide treatment (P- value 0.8299) Table 3. Nine arthropod species belonging to five orders and six families were found in the field plots. Abundance of all the herbivore species found within the treated and control plots is reported in Table 4. The most common arthropod species were *Brevicoryne brassica* L and *Myzus persicae* Sulz aphids. Diamondback moth (*Plutella xylostella*) was also common in collard green and Swiss chard. The crop damage was mostly caused by the aphids and diamondback moths. Thrips and tobacco white fly were the least common pests, which were occasionally spotted in tomato.

Table 3: Results of one-way ANOVA examining the effect of stinging nettle pesticide on arthropod species abundance. This table presents the source of variation, degrees of freedom (d.f), Mean squares (MS), F-value and P-values.

Source of Variation	df	Mean square	F-value	P-value
Treatment	1	1949.3	0.05	0.8299

Predators and Parasitoids

Other predator and parasitoids that were found are those that feed on aphids and diamondback moth. The abundance of three predator species that were occasionally observed during scouting is presented in Table 4. Lady birds (*Hyppodamia variegate* Goeze) were mostly eating aphids; Parasitoid *Diadegma semiclausum* and *Cotesia plutellae* were both preying on diamondback moths.

Table 4: Herbivore species and total number found on the three crop species treated with *Urtica diversifolia* extracts or control treatment. The data are summaries for 9 weeks of sampling.

HERBIVORE					TREATMENT	
Order	Family	Species Name	Status	Host	Control	Pesticide
Hemiptera	Aphidae	*Brevicoryne brassicae* (L)	Pest		704	595
Hemiptera	Aphidae	*Myzus persicae* (Sulz-)	Pest		256	231
Acari	Tetranychidae	*Tetranychus telarius*	Pest		152	10
Coleoptera	Coccinellidae	*Hyppodamia variegate* (Goeze)	Predator	Aphids	4	3
Lepidoptera	Plutellidae	*Plutella xylostella* (L)	Pest		35	39
Thysanoptera	Thripidae	*Thrips tabaci* Lindeman	Pest		15	11
lepidoptera	Noctoidae	*Agrotis spp* (cutworms)	Pest		36	10
Hemiptera	Aleyrodidae	Tobacco white fly	Pest		0	3
Unknown	Unknown	Beetle (Unknown spp)	Pest		2	1
Hymenoptera	Braconidae	*Cotesia plutellae*	Predator	*Plutella xylostella*	3	5
Hymenoptera	Ichineumonidae	*Diadegma semiclausum*	Predator	*Plutella xylostella*	4	7
Total					1213	915

Pest Damage

Pest damage proportion were analyzed by analysis of variance for repeated measures using Statistical Analysis Software (SAS) V8 software to test the significance of treatment effects, week effects, treatment x species interactions, week x species interactions, and species x treatment x week interactions. This analysis was done in order to determine whether the treatment effects is the same in the three species of crops and whether there were any differences in pest damage levels through the nine weeks. Two levels of pesticide damage categories were used: Light damage category which was determined by damage score of between 1 and 2 while heavy damage category referred to damage score of 3 and 4. The extent of pest damage was determined by calculating the number of plant falling in either of the damage category over the total number of plants sampled. The effect of pesticide treated plot resulted in a significant reduction in pest damage levels $P < 0.05$ (Table 5 and Table 6).

Light Damage Category

From ANOVA results, the plots treated with stinging nettle pesticide were significantly different from the control plots (P-value 0.0004) as shown on Table 5. Although there was no significant interaction between the treatment and the week, the pest damage was different each week as illustrated by Figure 12. Similarly, there was no significant difference in the interaction between treatment x crop species and thus the treatment effect was not dependent on crop species (Table 5). Based on Tukey's Studentized Range Test (HSD) test for proportion, the mean pest damage proportion was significantly higher for the pesticide treatment (0.30247) than the control treatment (0.20833) in the light damage category (Table 6). In all the three crop species, the pesticide treated plots fell on the lower damage levels of between 1 and 2. In the lower damage category pesticide treatment had a significantly higher damage level than the control plots in all the three species (Figure 12). Although during the first week of sampling the control plots had a relatively higher damage level in the light damage category, the pesticide treated plots had a higher damage from the second week to the ninth week of observation (Figure 12). This means that majority of the control plots fell in the higher damage levels of 3- 4 respectively (Figure 11).

Table 5: Analysis of Variance showing the effect of stinging nettle pesticide on pest damage (Light damage category). This table shows the source of variation, degrees of freedom (d.f), Mean squares (MS), F-value and P-values.

Source of Variation	df	Mean square	F-value	P-value
Species	2	0.421	11.40	<.0001
Treatment	1	0.475	12.88	0.0004
Week	8	0.857	2.89	0.0049
Treatment* Species	2	0.056	0.76	0.4691
Species *Week	16	1.857	3.14	0.0001
Treatment*Week	8	0.2329	0.79	0.6131
Treatment*Species*Week	16	0.797	1.35	0.1738

Table 6: Tukey's Studentized Range (HSD) Test for Pest Damage Proportion; Means with different letters are significantly different.

Treament	Mean Proportion	Tukey Grouping
Pesticide	0.30247	A
Control	0.20833	B

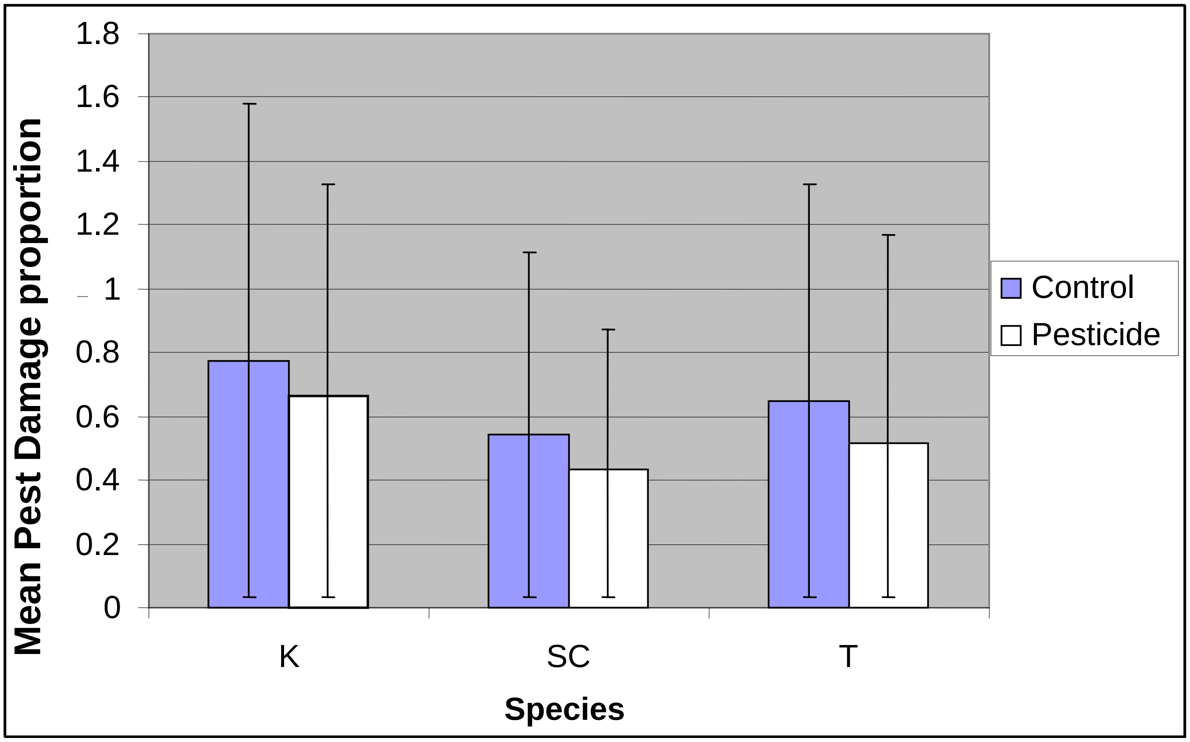

Figure 11: Effect of *U. diversifolia* pesticide on mean pest damage proportion on the three species Collard green (K), Swiss chard (SC) and Tomato (T). Error bars represents 95% confidence interval.

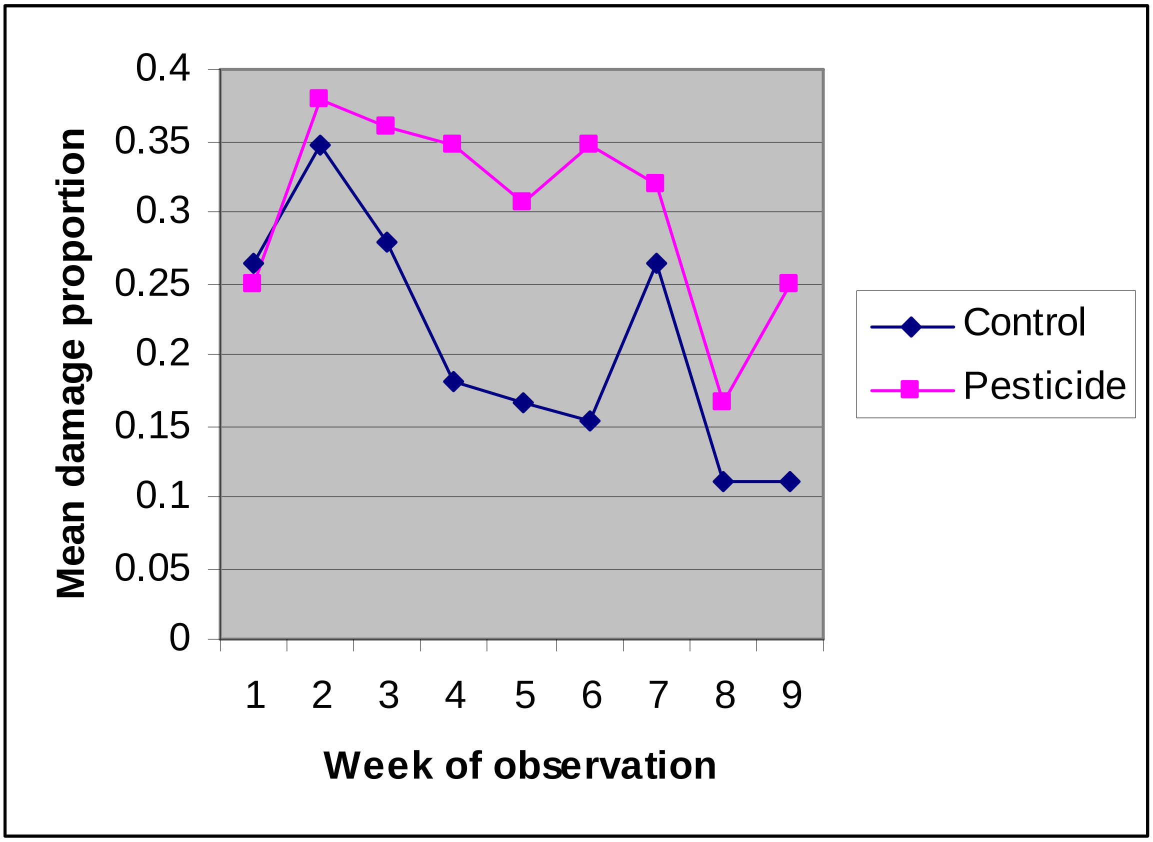

Figure 12: Effect of *U. diversifolia* on pest damage proportion over time (Light Damage Category) for Collard green (K), Swiss chard (SC) and Tomato (T) combined.

High Damage Category

From ANOVA results, there was significant treatment effect (P-value 0.0001) Table 7. Based on Tukey's Studentized Range Test (HSD) for pest damage proportion, the mean pest damage proportion was significantly lower for the pesticide treatment (0.53858) than the control treatment (0.65432) Table 8. This means that the pest damage on the control plots was significantly higher than the plots treated with *Urtica diversifolia* because most of the sampled plants fell in the range of 3-4 damage score. Although there was no significant difference in treatment X week interactions and treatment X species X week interactions as shown on Table 7, pest damage per week was statistically significant (P -value < 0.0001). The pest damage proportion was different every week as illustrated in Figure 13. The one way ANOVA analysis indicated that the control plots resulted in a statistically higher mean pest damage during week 4 and week 6 (P –value < 0.05) as compared to any other week (Figure 13, Table 9 and Table 10). In addition the Tukey's HSD test also showed similar results as illustrated in Table 11 and Table 12. The highest pest damage level was during week 4 for all the crops in the control plots and lowest during week 1 in comparison to the pesticide treated plots as illustrated in the Tukey's mean comparison for pest damage levels through the nine weeks of observation (Table 13). However, collard green crop showed a different result in that the pesticide treated plots of the collard green had a higher pest damage level than the control plot (Figure 14). On Swiss chard crop species, the pesticide treatment resulted in a significant reduction of pest damage (Figure 15).

Table 7: Analysis of Variance showing the effect of stinging nettle pesticide on pest damage (High damage category).This table shows the source of variation, degrees of freedom (d.f), Mean squares (MS), F-value and P-values.

Source of Variation	df	Mean square	F-value	P-value
Species	2	0.421	11.40	<.0001
Treatment	1	0.475	12.88	0.0001
Week	8	0.857	2.89	<.0001
Treatment* Species	2	0.056	0.76	0.9434
Species *Week	16	1.857	3.14	<.0001
Treatment*Week	8	0.2329	0.79	0.3917
Treatment*Species*Week	16	0.797	1.35	0.1738

Table 8: Tukey's Studentized Range (HSD) Test for Pest Damage Proportion; Means with different letters are significantly different.

Treatment	Mean Proportion	Tukey's Grouping
Control	0.65452	A
Pesticide	0.53858	B

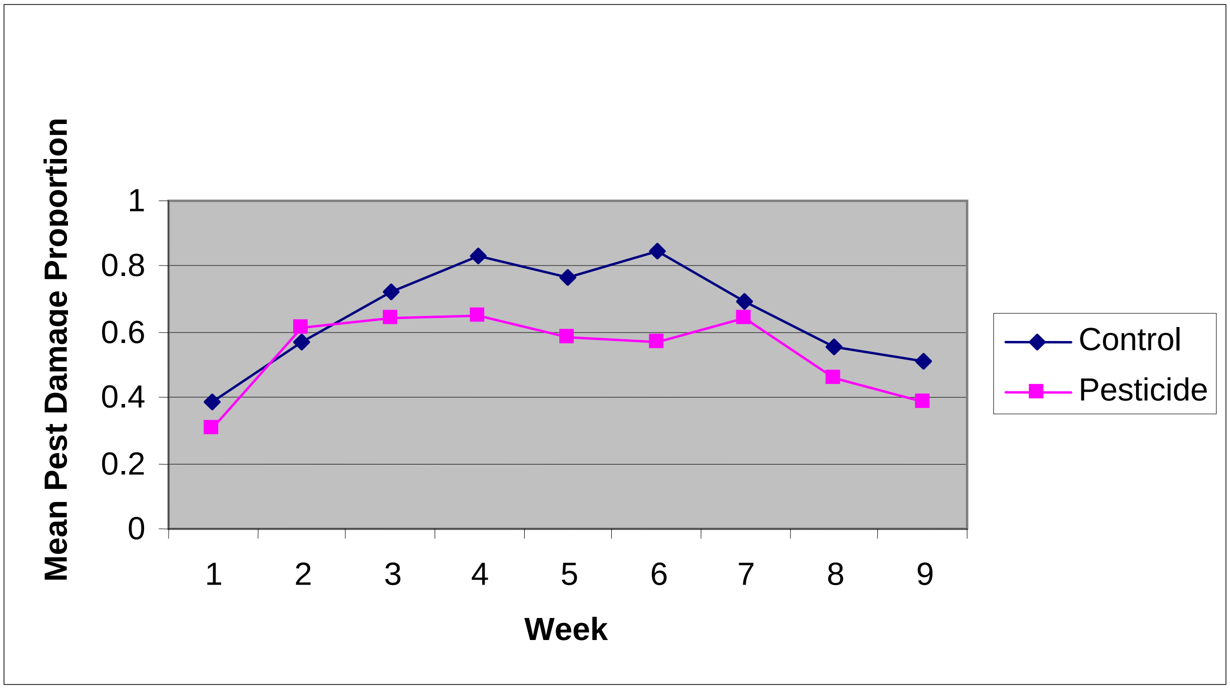

Figure 13: Effect of *U. diversifolia* on pest damage proportion over time (High Damage Category)

Table 9: Analysis of Variance showing the effect of stinging nettle pesticide on pest damage (High damage category) during week 4;This table shows the source of variation, degrees of freedom (d.f), Mean squares (MS), F-value and P-values.

Source of Variation	df	Mean square	F-value	P-value
Species	2	0.0706	1.60	0.2273
Treatment	1	0.1956	4.42	0.0483

Table 10: Analysis of Variance showing the effect of stinging nettle pesticide on pest damage (High damage category) during week 6;This table shows the source of variation, degrees of freedom (d.f), Mean squares(MS), F-value and P-values.

Source of Variation	df	Mean square	F-value	P-value
Species	2	0.2118	6.20	0.0080
Treatment	1	0.4629	13.56	0.0015

Table 11: Tukey's Studentized (HSD) Test for Pest Damage proportion for Week 4; Means with different letters are significantly different.

Treatment	**Mean Proportion**	**Tukey's Grouping**
Control	0.8333	A
Pesticide	0.65278	B

Table 12: Tukey's Studentized (HSD) Test for Pest Damage proportion for Week 6; Means with different letters are significantly different.

Treatment	Mean Proportion	Tukey's Grouping
Control	0.84722	A
Pesticide	0.56944	B

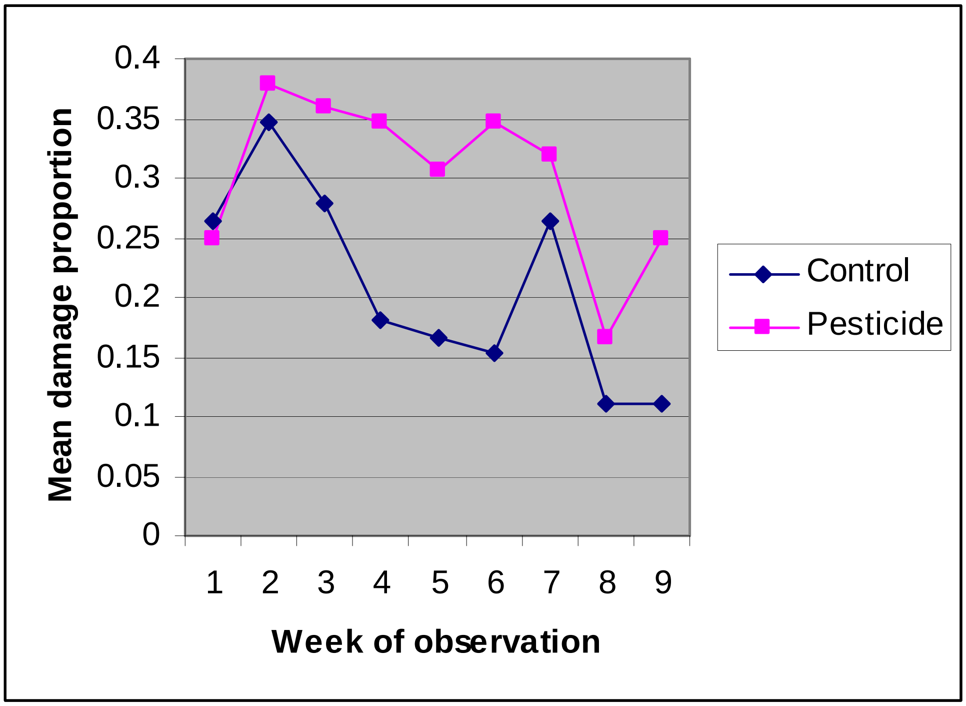

Figure 14: Effect of *U. diversifolia* on pest damage proportion for Collard green plants over time (High Damage Category)

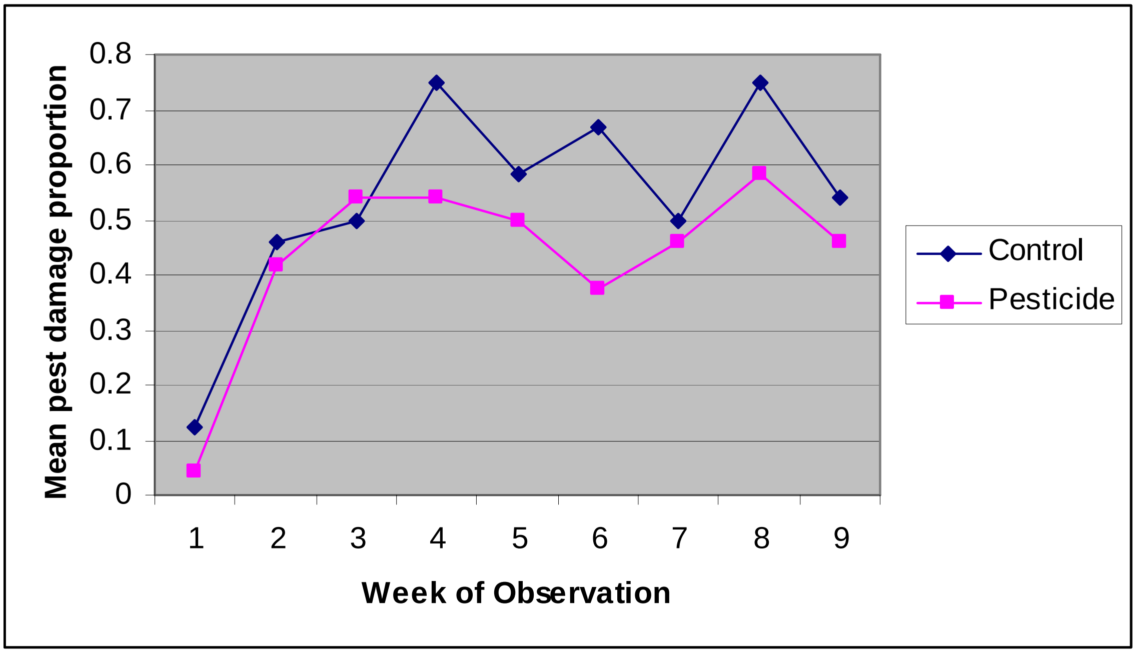

Figure 15: Effect of *U. diversifolia* on pest damage proportion for Swiss chard plants over time (High Damage Category)

Table 13: Tukey's Studentized Range (HSD) Test for Pest Damage Proportion; weeks with the same letter are not significantly different.

Tukey Grouping			Mean	N	Week
	A		0.74306	24	4
	A				
	A		0.70833	24	6
	A				
B	A		0.68056	24	3
B	A				
B	A		0.67361	24	5
B	A				
B	A		0.66667	24	7
B	A				
B	A	C	0.59028	24	2
B		C			
B	D	C	0.50694	24	8
	D	C			
	D	C	0.45139	24	9
	D				
	D		0.34722	24	1

Height Growth

Height growth data was analyzed by analysis of variance for repeated measures using Statistical Analysis Software (SAS) V8 software to test the significance of treatment effects, week effects, treatment x species interactions, week x species interactions, and species x treatment x week interactions on height growth. This analysis was done in order to determine whether the treatment effects on height growth is the same in the three species of crops and whether there were any differences in height growth levels through the nine weeks. Height growth was calculated by subtracting the height observed the previous week from height observation in the sampling week. Based on overall F- test results at alpha 0.05 significant level, there was no significant treatment effects on height growth (P value = 0.6013) Table 14. However the height growth was different every week. From the ANOVA result, week effects resulted in a significantly different height growth $P < 0.0001$. This is best illustrated in Figure 16 and Figure 17.

Based on the Tukey's Studentized Range (HSD) test, Week 4, though not significantly different from week 5, 3, 2 and 6 resulted in a significantly higher mean height growth than week 7, 8 and 9 Figure 16 and Figure 17. Week 9 though not different from week 8, resulted in a significantly lower mean height growth than all the other weeks (Figure 16 and Figure 17).

There was also a significant week x species interactions, meaning that the height growth on each species differed by the number of weeks (P value < 0.05) Table 14. Figure 18, figure 19 and figure 20 illustrates differences in height growth between Collard green, Swiss chard and tomato plants that were treated with *U. diversifolia* pesticide compared to control. Pesticide treatment on Collard green crop species resulted in a higher mean height growth during the second, third and sixth week (Figure 18). On Swiss chard crop species, control treatment resulted in a relatively higher mean height growth during the nine week period than the pesticide treated plants though not statistically different (Figure 19). Overall, there were no significant differences in the effect of *U. diversifolia* pesticide on height growth between the species (Figure 21).

Table 14: Analysis of Variance showing the effect of *Urtica diversifolia* pesticide on Height Growth.

Source of Variation	df	Mean square	F-Value	P-Value
Treatment	1	0.154	0.27	0.6013
Week	7	19.810	35.12	<0.0001
Treatment* Species	2	0.588	1.04	0.3551
Species *Week	14	4.769	8.46	<0.0001
Treatment*Week	7	0.662	0.17	0.3213
Treatment*Species*Week	16	0.797	1.35	0.2689

Table 15: Tukey's Studentized Range (HSD) Test for Height Growth over time; weeks with the same letter are not significantly different.

Week	Mean Height Growth	Turkey Grouping
4	3.0250	A
5	2.8292	A
3	2.7542	A
2	2.4188	A
6	2.3667	A
7	1.4208	B
8	0.9083	BC
9	0.7125	C

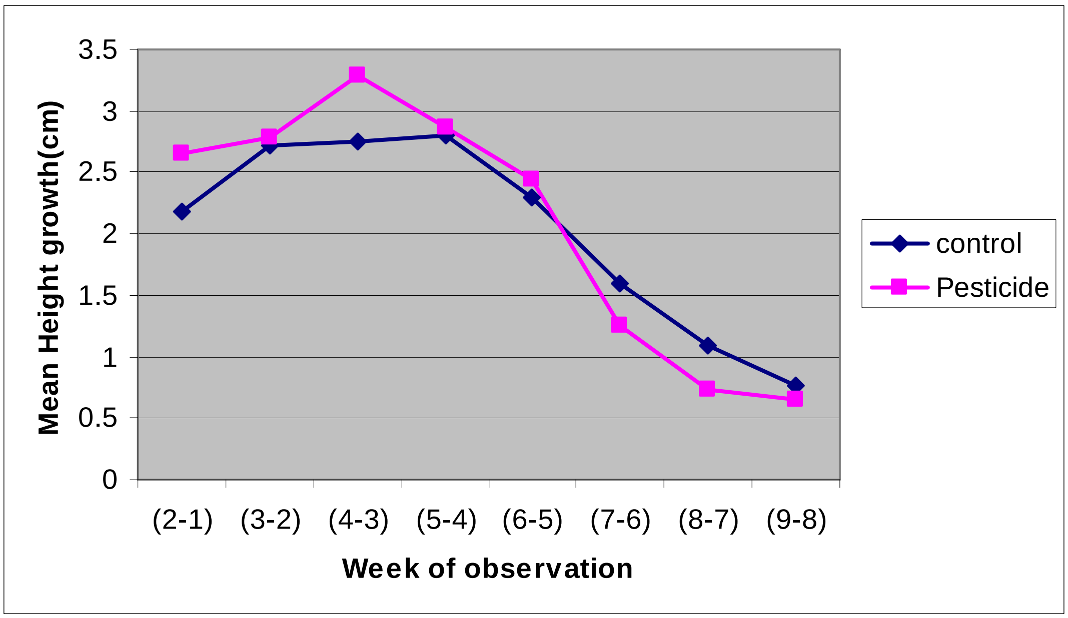

Figure 16: Effect of *Urtica diversifolia* Pesticide on Plant Height Growth over time compared to control treatment.

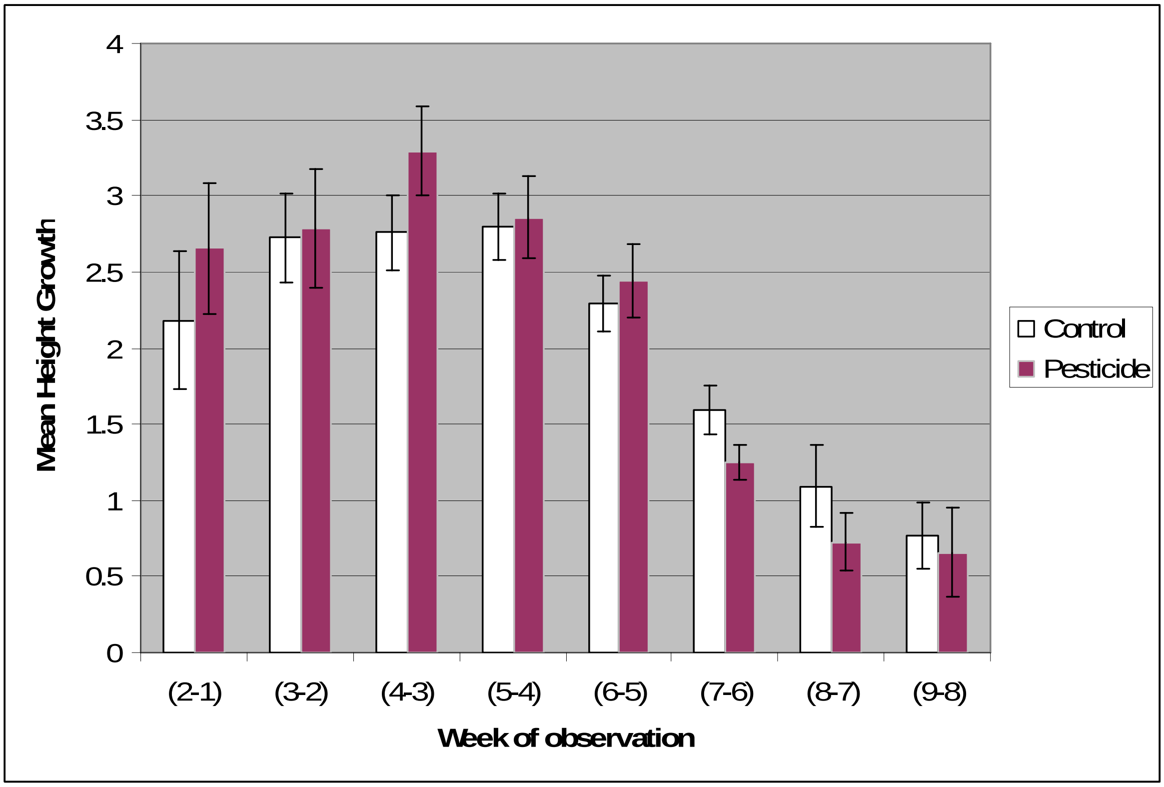

Figure 17: Effect of *Urtica diversifolia* Pesticide on Plant Height Growth over time compared to control treatment. Error bars represent standard errors at 0.05 significance level.

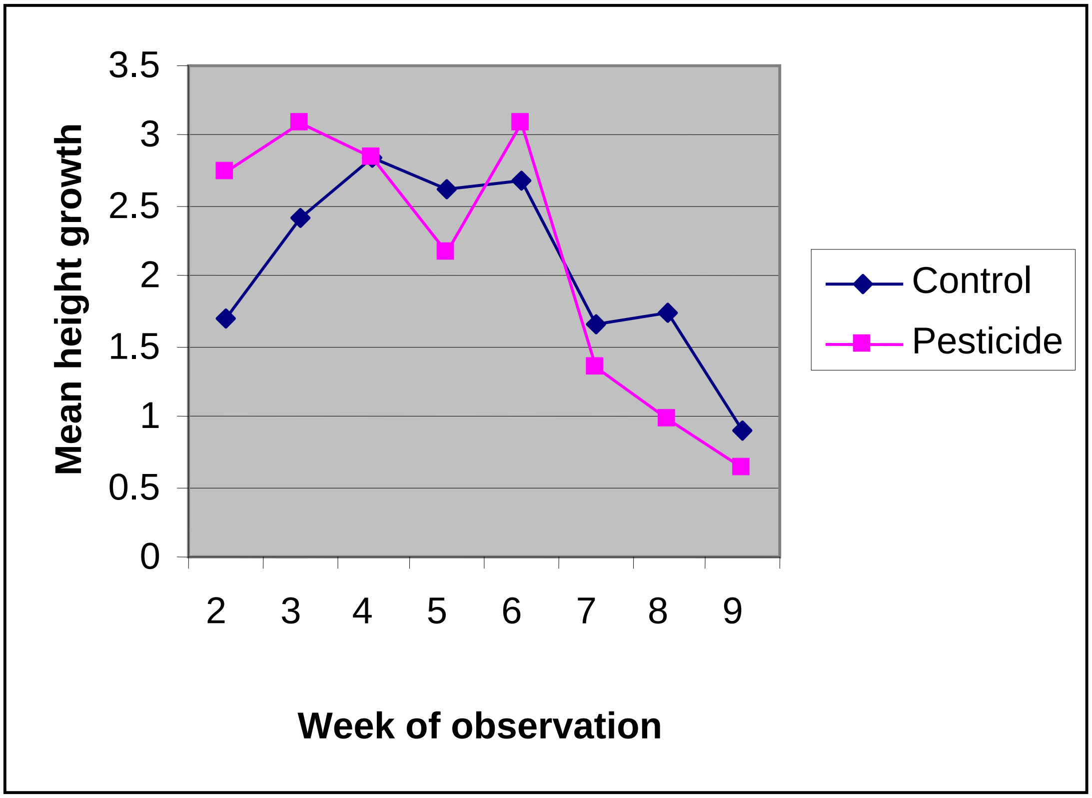

Figure 18: Effect of *Urtica diversifolia* Pesticide on Plant Height Growth on Collard green plants over time.

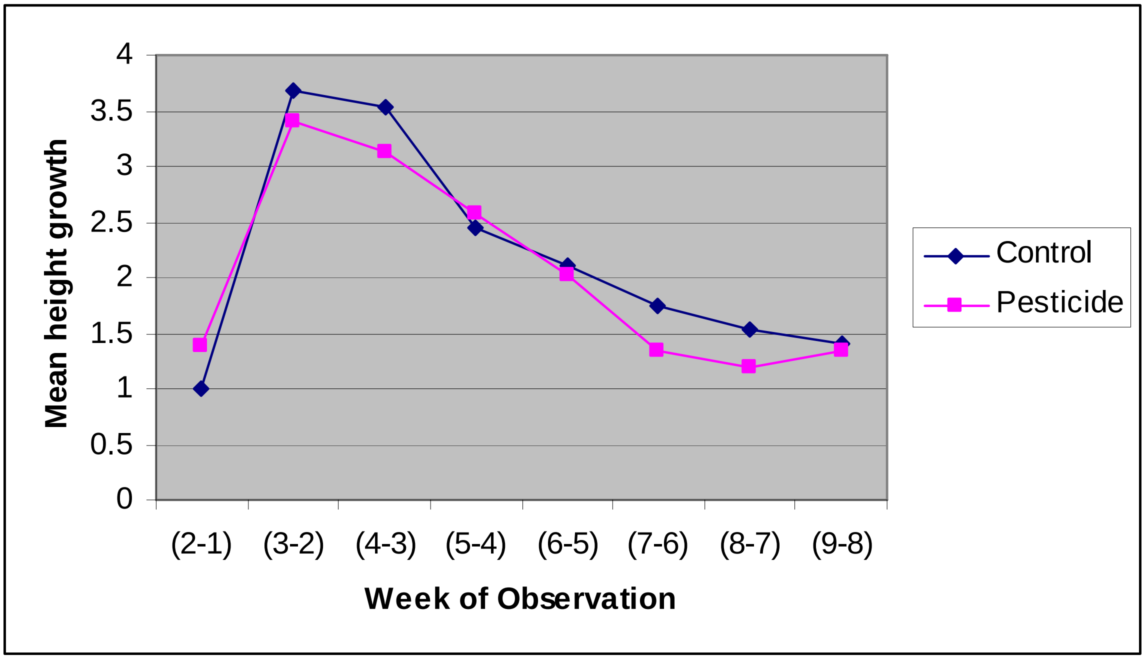

Figure 19: Effect of *Urtica diversifolia* Pesticide on Plant Height Growth on Swiss chard plants over time.

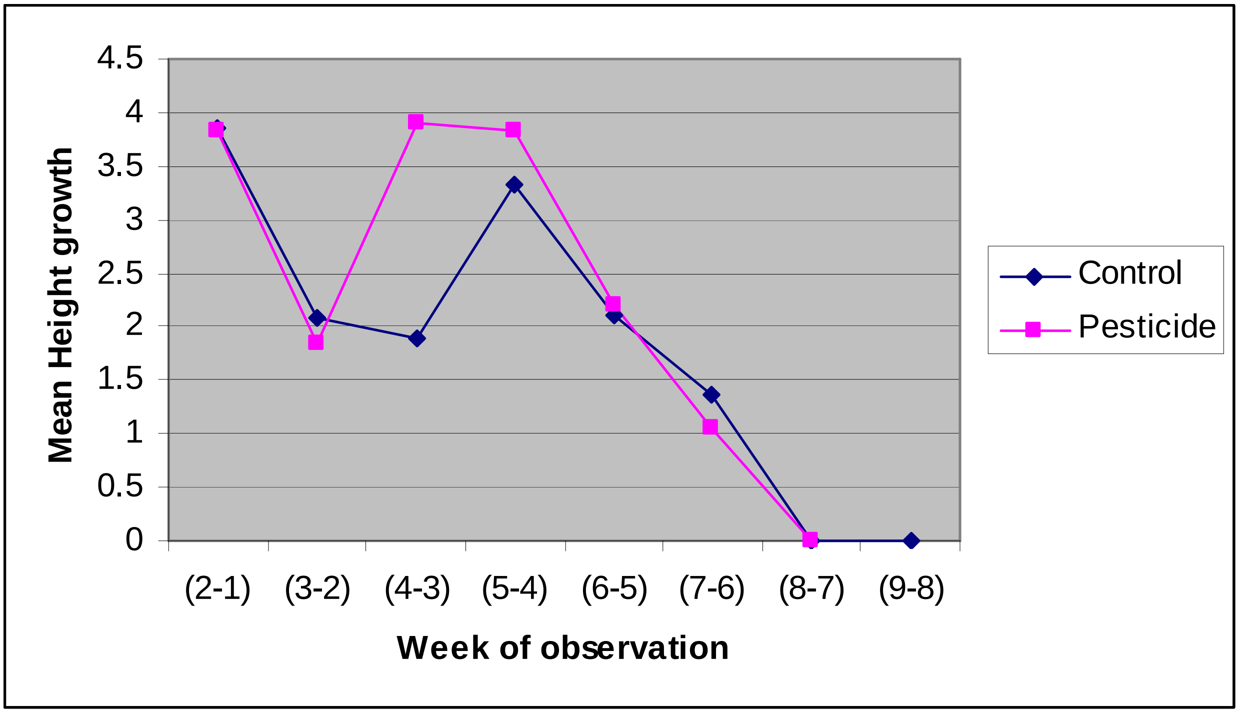

Figure 20: Effect of *Urtica diversifolia* Pesticide on Plant Height Growth on Tomato plants over time.

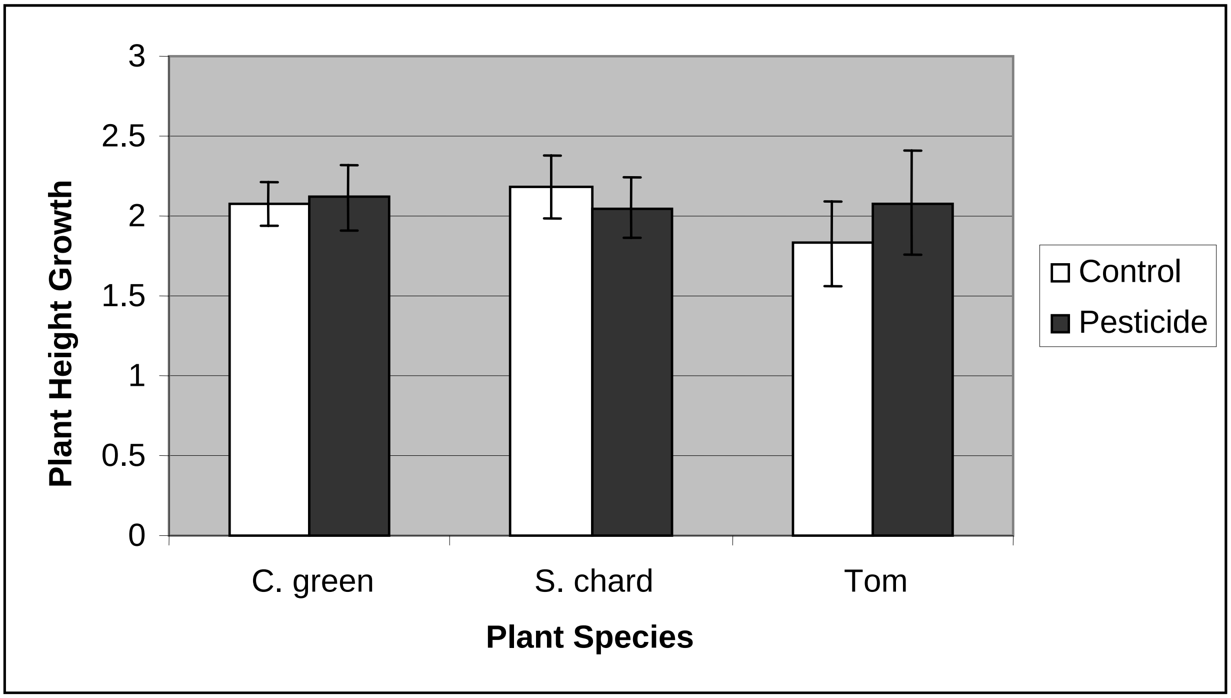

Figure 21: Effect of *Urtica diversifolia* Pesticide on Plant Height Growth (cm) on Collard green (K), Swiss chard (SC) and tomato (T). Error bars represents standard error.

DISCUSSION

Effect of *Urtica diversifolia* on Pest damage

H0: There is no difference in the level of pest damage between the stinging nettle pesticide treated plants and the control plants.

H1: Stinging nettle pesticide treatment has an effect on pest damage levels.

There were statistically significant differences between the amount of pest damage on the plots treated with *U. diversifolia* and the control plots (P-value < 0.05). Although the pest abundance on treated plots and the control plots was not statistically different, the pest damage was significantly lower on plants treated with *U. diversifolia* than in the control plots. The damage was significantly higher for the control plots with higher number of plants sampled falling under higher pest damage categories (damage score of 3-4). This experiment confirms that feeding damage by arthropods species was significantly lower on plants treated with *U. divesifolia* pesticide. Reduced feeding damage may be attributed to antifeedant properties or repellant properties of *U. diversifolia.* Based on the results of this study the amount of pest damage in the control plots was significantly higher than the pesticide treated plots (P-value < 0.05). Thus, the null hypothesis that stated that, there is no difference in the level of pest damage between the stinging nettle pesticide treated plants and the control plants was rejected.

Effect of *Urtica divesifolia* on Fresh Biomass Weight

H0: There is no difference in average fresh biomass yield between the pesticide treated plots and the control plots.

H1: The average biomass yield will be higher on the stinging nettle pesticide treated plots than on the control plots.

Although there was less damage in the treated plots than the control plots, the final fresh biomass weight of the collard green and Swiss chard harvested at nine weeks was not statistically different. This may have been limited by the sample size, there is a possibility that if a larger sample size was used, the results would have been different. More plants would have been sampled if the outer rows were not deliberately left to avoid edge effect. The limited land size that the farmers provided for experimental trials would not have been enough to set more experimental units. Similarly, the concentration that we used in this experiment was what farmers considered as the best based on trial and error validation. There is a likelihood that if a higher concentration level was used the stinging nettle pesticide would have resulted to a significant effect on fresh biomass weight. Therefore, there is a need for scientific validation of the used pesticide concentration. Because the P-value for this test was greater than 0.05, the null hypothesis that stated that the fresh biomass yield between the pesticide treated plots and control plots is equal was accepted.

Effect of *Urtica diversilfolia* on Pest Abundance

H0: There is no difference in populations of arthropod species between the pesticide treated plots and the control plots.

H1: Population of arthropod species will be reduced on plants treated with stinging nettle pesticide.

Based on the results of this experiment, the main insect pests found in brassica species (Collard green and Swiss chard) was *Brevicoryne brassica*, *Myzus persicae and Plutella xylostella.* In many cases the total population of *Plutella xylostella* was almost similar between the treated plots and the control plots. This may also have contributed to the resulting similarity in the biomass yield between treated plots and the control plots.

However, the reduced amount of damage found in the treated plots would suggest that even during the periods of high pest infestation, the reduced feeding by aphids and diamondback moth species on plants treated with botanical pesticides is a more important factor than the actual population density in reducing the damage and improving the quality of the yield. Because the P-value for this test was greater than 0.05, the null hypothesis that stated that there is no difference in populations of arthropod species between the pesticide treated plots and the control plots was accepted.

Effect of *Urtica diversifolia* on Height Growth

H0: There is no difference in average height growth between the pesticide treated plots and the control plots.

H1: The average height growth will be higher on the stinging nettle pesticide treated plots than on the control plots.

The *Urtica diversifolia* pesticide did not have significant impact on height growth. However, the pesticide increased height growth during the first four weeks after which the control plots had a higher height growth. Plants treated with pesticide had the highest mean height during the fourth week measurement. This means that the pesticide boosted growth rate at the beginning though not statistically significant. There were no significant differences in effect of *U. diversifolia* pesticide on plant growth between the species. Because the P-value for this test was greater than 0.05, the null hypothesis that stated that there is no difference in average height growth between the pesticide treated plots and the control plots was accepted.

CONCLUSION

In Kenya, tomatoes, collard green and Swiss chard are grown through out the year and are staple food as well as income sources for resource poor farming communities. The majority of the farmers cannot afford expensive chemical pesticides and the pest control is limited to traditional techniques particularly cultural control, intercropping, crop rotation. Botanical pesticide therefore provides an additional natural pest control technique. However, botanical pesticide alone maybe insufficient to provide adequate protection and therefore requires integration with other control techniques such as biological control.

Application of *Urtica diversifolia* pesticide on commonly grown vegetables in Kamweti significantly reduced crop damage by the pests. This was demonstrated by the lowest crop damage of the pesticide treated plots in the higher pest damage category. Although the insect pest population density was as high for the treated plants as it was on the control plots, the damage on the plants treated with *U. diversifolia* was significantly lower. Therefore, this experiment shows that the reduced feeding by the insect pests particularly aphids and diamondback moth is a more important factor in the reduction of the damage than the actual population density. More on-farm research is needed to demonstrate whether stinging nettle has an impact on total biomass yield and plant growth which might be of economical importance to the farmers.

OVERALL CONCLUSION

Farmers play a very important role in sustainable development due to their enormous amount of indigenous knowledge and experiential learning techniques. The training needs assessment offered an important participatory tool that enabled farmers to be able to highlight some of their challenges and look for solutions for addressing their problems together. The training workshops carried out during the study period empowered the farmers by equipping them with the sustainable agriculture and organic farming principles. This study is a good illustration of bottom up approach towards addressing sustainable development issues which requires an appropriate level of community participation.

The majority of the resource poor farmers cannot afford synthetic chemical pesticide and therefore they often rely on traditional farming techniques to control insect problems. Botanical pesticides offer an alternative pest control techniques that can successfully be adopted by small scale farmers. Results from this thesis illustrate that botanical extracts like stinging nettle pesticide have a positive impact on reduction of crop losses due to pest damage. Stinging nettle resulted in a significant reduction of pest damage and thus, small scale farmers would be able to reduce their farm inputs and consequently improve the marketable yield of their crops by utilizing the stinging nettle pesticide. Through combination of locally available resources and existing indigenous knowledge farmers have the capacity to increase the profitability of their farming enterprises. Processing and marketing of stinging nettle among the Kamweti farmers group in Kenya is one of the success case studies where farmers have successfully utilized the local plant resources to solve pest problems. However before further recommendation is made a further study to investigate the environmental and mammalian toxicity is needed.

RECOMMENDATIONS

Plants products are complex and may contain variable mixtures of chemical compounds with possible negative side effects on humans. Before any recommendation is made on expanding the use of *Urtica diversifolia* as a pesticide to control pest problems by other smallholder farming communities in Kenya, a detailed scientific test of its environmental and human toxicity is required. Currently there is no study that has been carried out to investigate the mammalian toxicity of *Urtica diversifolia.*

It is also notable that Kamweti stinging nettle group has been using the *Urtica diversifolia* pesticide on both monocrops and intercrops. However, during the farmers' informal interviews, the majority of the farmers indicated that the pesticide was more effective when the major vegetables are intercropped than when grown on monocrops. It might be of interest to carry out a further study to investigate the impacts of *Urtica diversifolia* on Swiss chard, tomato and collard green when intercropped to validate the claims of the farmers that pesticide improved yield on their crops. However, if tomatoes, collard green and Swiss chard have to be intercropped, then adequate spacing should be provided to minimize shading of brassica crops by tomatoes. The use of compost manure to improve soil fertility is strongly encouraged. In addition, the sample size should be larger and this translates to willingness of the farmers to set aside a larger portion of their land for experimental study.

The insignificant results on biomass weight and height growth may have been attributed to the pesticide concentration of 1:5 that the farmers had claimed worked. There is a need to carry out a further scientific study to determine the best concentration for the pesticide. This current study focused on the concentration of 1:5 that farmers perceived as the best based on their experiences.

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APPENDIX 1

2.3 Group Members and Students in Charge

Group One: farmers from Karani area, above FTC

Seven farmers and one student

Group two: Farmers from Ngamba area

Seven farmers and one student

Group Three. Farmers from Kieheria area below Kamweti market centre

Seven farmers and one student

Group Four. Farmers from Karuti area

Seven farmers and one student

Appendix 11: Insect Damage and disease scores

INSECT DAMAGE

1= No visible damage

2= 1-20 % of the leaf Damage (Light Damage)

3= 21- 30% of the plant had leaf damaged

4= 31-40%

5= 41 -50%

6= Over 50% of the plant had leaf damage

7= Plant Death

Appendix: 111. ANALYSIS OF SOIL RESULTS FOR NITROGEN, PHOSPORUS, POTASSIUM AND PH
DATE SAMPLED: July 7-9, 2006
DATE ANALYSED: July 15, 2006
(-) = missing data

	farmer	p.H test	Phosphorus test	Nitrogen test	Potassium test
1.	Farmer 1	5.0	Trace	Trace	Very high
2	Farmer 2(Banana)	4.0	Trace	Trace	High
3	Farmer 3	4.0	low	Trace	High
4	Farmer 4	5.0	Trace	Trace	High
5	Farmer 5(Coffee)	4.0	Trace	Trace	Medium High
6	Farmer 6	5.0	Trace	Trace	Very high
7	Farmer 2 (Nursery soil)	5.0	Low	Trace	Very high
8	Farmer 5 (Maize soil)	5.0	Trace	Trace	Very high
9	Farmer 7	5.0	Trace	Trace	Very high
10	Farmer 8	5.0	Trace	Trace	Very high
11	Farmer 9	4.0	Trace	Trace	High
12	Farmer 10	4.0	Trace	Trace	High
13	Farmer 11	5.0	Trace	Trace	Very high
14	Farmer 12	4.5	Trace	Trace	Very high
15	Farmer 13	4.0	Trace	Trace	High
16	Farmer 14	5.0	Trace	Trace	High
17	Farmer 15	5.0	Trace	Trace	Very High
18	Farmer 16	5.0	Trace	Trace	High
19	Farmer 17	4.0	Trace	Trace	Very High
20	Farmer 18	5.0	Trace	low	High
21	Farmer 19	4.0	Trace	Trace	High
22	Farmer 20	5.0	Trace	Trace	High
23	Farmer 21	5.0	Trace	Trace	High
24	Sample A	5.0	Low	Trace	High
25	Sample B	4.0	Trace	Trace	High
26	Sample C	5.5	Trace	-	Very high
27	Sample D	5.0	Trace	Trace	Medium high
28	Sample E	5.0	Trace	-	High

Appendix: 1V: Effects of U. diversifolia pesticide on Fresh Biomass yield for Tomato (T), Kale (K) and Swiss Chard (SC) Species harvested at the age of nine Weeks.

Species	Treatment	Plot #	Replication	Fresh Biomass weight
T	C	1	1	0
T	C	2	2	0
T	C	6	3	0
T	C	7	4	0
T	P	3	1	0
T	P	4	2	0
T	P	5	3	0
T	P	8	4	0
K	C	2	1	0.8
K	C	5	2	1.4
K	C	7	3	0.8
K	C	8	4	1
K	P	1	1	1
K	P	3	2	1
K	P	4	3	1.2
K	P	6	4	1.2
SC	C	1	1	1.5
SC	C	3	2	0.2
SC	C	4	3	1
SC	C	8	4	1
SC	P	2	1	1.4
SC	P	5	2	1
SC	P	6	3	0.2
SC	P	7	4	1

Appendix: V. Weekly Observations for Early Blight Progress in Tomato

			Week of Observation								
Crop	Plot	Treatment	LS 1	LS 2	LS 3	LS 4	LS 5	LS 6	LS 7	LS 8	LS 9
Tomato	1	Control	1	3	4	5	5	5	5	6	6
	2	Control	1	3	3	4	4	5	5	6	6
	3	Pesticide	1	2	2	3	4	5	5	6	6
	4	Pesticide	1	1	1	3	4	4	5	6	6
	5	Pesticide	1	1	1	2	4	5	5	6	6
	6	Control	1	2	3	3	4	4	5	6	6
	7	Control	1	2	3	4	5	5	5	6	6
	8	Pesticide	1	1	2	5	5	5	5	6	6

Appendix: V11. Weekly Observations for plant height in cm

			Week of Observation								
Crop	Plot	Treatment	PH 1	PH2	PH3	PH4	PH5	PH6	PH7	PH8	PH9
Tomato	1	Control	13.4	18	21.2	23.1	26.3	28.2	29.2	-	-
	2	Control	13.0	15	17.4	19.3	23.4	25.3	26.1	-	-
	3	Pesticide	14.8	16.6	18.4	21.2	24.2	27.4	28.3	-	-
	4	Pesticide	10.6	12.7	16.3	19.7	23.8	25.6	25.5	-	-
	5	Pesticide	11.00	16.8	18.2	22.3	26.7	28.5	29.1	-	-
	6	Control	10.5	13.5	15.2	17.5	20.7	23.1	25.6	-	-
	7	Control	10.2	16.0	17.0	18.5	21.3	23.5	24.9	-	-
	8	Pesticide	12.75	17.8	18.4	23.7	27.5	29.5	30.3	-	-
Kale	1	Pesticide	6.5	9.5	11.5	13.7	15.3	18.5	19.8	21.6	22.
	2	Control	6.75	8.5	10.5	12.9	15.1	17.1	18.5	20.2	21.2
	3	Pesticide	8.5	10.5	14.5	17.5	19.3	22	23.3	23.9	24.4
	4	Pesticide	7.25	10.25	14.0	16.3	19.1	23.2	24.5	25.1	25.9
	5	Control	7.0	8.5	11.2	14.1	17.3	20.1	22.3	24.1	25.3
	6	Pesticide	7.75	10.7	12.8	16.7	19.2	21.6	23.1	24.0	24.8
	7	Control	6.0	7.5	9.4	11.9	14.5	17.9	19.1	21.0	21.7
	8	Control	5.25	7.25	10.3	12.8	15.3	17.6	18.8	20.1	20.4
Spinach	1	Control	3.75	4.75	9.2	12.1	13.3	15.1	17.0	19.7	20.3
	2	Pesticide	4.2	5.7	9.8	14.5	16.2	17.3	18.5	19.5	21.5
	3	Control	3.5	4.5	8.2	12.3	14.5	17.1	18.2	19.3	21.6
	4	Control	3.9	4.7	8.6	12.6	15.2	16.2	17.9	19.1	20.9
	5	Pesticide	4.7	5.9	7.4	10.2	13.5	15.5	17.1	18.7	19.5
	6	Pesticide	4.3	6.3	10.4	12.5	14.8	16.7	17.6	18.5	20.3
	7	Pesticide	6.1	6.9	10.8	13.7	15.2	18.3	20	21.3	22.1
	8	Control	4.3	5.5	8.1	11.3	15.1	18.1	20.4	21.5	22.4

Appendix: IX. Weekly Observations for pest damage proportions

Week	Trt	Plot	Rep	Species	Code	no_plants	Proportion
1	C	1	1	T	1	0	0
1	C	1	1	T	23	1	0.166667
1	C	2	2	T	1	3	0.5
1	C	2	2	T	23	3	0.5
1	C	6	3	T	1	3	0.5
1	C	6	3	T	23	3	0.5
1	C	7	4	T	1	2	0.333333
1	C	7	4	T	23	4	0.666667
1	P	3	1	T	1	3	0.5
1	P	3	1	T	23	3	0.5
1	P	4	2	T	1	2	0.333333
1	P	4	2	T	23	4	0.666667
1	P	5	3	T	1	3	0.5
1	P	5	3	T	23	3	0.5
1	P	8	4	T	1	2	0.333333
1	P	8	4	T	23	4	0.666667
1	C	2	1	K	1	2	0.333333
1	C	2	1	K	23	4	0.666667
1	C	5	2	K	1	3	0.5
1	C	5	2	K	23	3	0.5
1	C	7	3	K	1	2	0.333333
1	C	7	3	K	23	4	0.666667
1	C	8	4	K	1	3	0.5
1	C	8	4	K	23	3	0.5
1	P	1	1	K	1	0	0
1	P	1	1	K	23	0	0
1	P	3	2	K	1	2	0.333333
1	P	3	2	K	23	1	0.166667
1	P	4	3	K	1	2	0.333333
1	P	4	3	K	23	3	0.5
1	P	6	4	K	1	3	0.5
1	P	6	4	K	23	3	0.5
1	C	1	1	SC	1	0	0
1	C	1	1	SC	23	0	0
1	C	3	2	SC	1	0	0
1	C	3	2	SC	23	0	0
1	C	4	3	SC	1	0	0
1	C	4	3	SC	23	2	0.333333
1	C	8	4	SC	1	1	0.166667
1	C	8	4	SC	23	1	0.166667
1	P	2	1	SC	1	1	0.166667
1	P	2	1	SC	23	0	0
1	P	5	2	SC	1	0	0
1	P	5	2	SC	23	1	0.166667
1	P	6	3	SC	1	0	0
1	P	6	3	SC	23	0	0
1	P	7	4	SC	1	0	0

1	P	7	4	SC	23	0	0
2	C	1	1	T	1	3	0.5
2	C	1	1	T	23	3	0.5
2	C	2	2	T	1	2	0.333333
2	C	2	2	T	23	4	0.666667
2	C	6	3	T	1	3	0.5
2	C	6	3	T	23	3	0.5
2	C	7	4	T	1	1	0.166667
2	C	7	4	T	23	5	0.833333
2	P	3	1	T	1	1	0.166667
2	P	3	1	T	23	5	0.833333
2	P	4	2	T	1	2	0.333333
2	P	4	2	T	23	4	0.666667
2	P	5	3	T	1	1	0.166667
2	P	5	3	T	23	5	0.833333
2	P	8	4	T	1	2	0.333333
2	P	8	4	T	23	4	0.666667
2	C	2	1	K	1	3	0.5
2	C	2	1	K	23	3	0.5
2	C	5	2	K	1	2	0.333333
2	C	5	2	K	23	4	0.666667
2	C	7	3	K	1	2	0.333333
2	C	7	3	K	23	4	0.666667
2	C	8	4	K	1	2	0.333333
2	C	8	4	K	23	4	0.666667
2	P	1	1	K	1	1	0.166667
2	P	1	1	K	23	5	0.833333
3	P	3	2	K	1	3	0.5
2	P	3	2	K	23	3	0.5
2	P	4	3	K	1	2	0.333333
2	P	4	3	K	23	4	0.666667
2	P	6	4	K	1	2	0.333333
2	P	6	4	K	23	4	0.666667
2	C	1	1	SC	1	0	0
2	C	1	1	SC	23	0	0
2	C	3	2	SC	1	2	0.333333
2	C	3	2	SC	23	4	0.666667
2	C	4	3	SC	1	2	0.333333
2	C	4	3	SC	23	4	0.666667
2	C	8	4	SC	1	3	0.5
2	C	8	4	SC	23	3	0.5
2	P	2	1	SC	1	4	0.666667
2	P	2	1	SC	23	2	0.333333
2	P	5	2	SC	1	3	0.5
2	P	5	2	SC	23	3	0.5
2	P	6	3	SC	1	4	0.666667
2	P	6	3	SC	23	2	0.333333
2	P	7	4	SC	1	3	0.5
2	P	7	4	SC	23	3	0.5
3	C	1	1	T	1	2	0.333333

3	C	1	1	T	23	4	0.666667
3	C	2	2	T	1	0	0
3	C	2	2	T	23	6	1
3	C	6	3	T	1	1	0.166667
3	C	6	3	T	23	5	0.833333
3	C	7	4	T	1	0	0
3	C	7	4	T	23	6	1
3	P	3	1	T	1	1	0.166667
3	P	3	1	T	23	4	0.666667
3	P	4	2	T	1	2	0.333333
3	P	4	2	T	23	4	0.666667
3	P	5	3	T	1	4	0.666667
3	P	5	3	T	23	2	0.333333
3	P	8	4	T	1	1	0.166667
3	P	8	4	T	23	5	0.833333
3	C	2	1	K	1	2	0.333333
3	C	2	1	K	23	4	0.666667
3	C	5	2	K	1	1	0.166667
3	C	5	2	K	23	5	0.833333
3	C	7	3	K	1	0	0
3	C	7	3	K	23	6	1
3	C	8	4	K	1	2	0.333333
3	C	8	4	K	23	4	0.666667
3	P	1	1	K	1	2	0.333333
3	P	1	1	K	23	4	0.666667
3	P	3	2	K	1	2	0.333333
3	P	3	2	K	23	4	0.666667
3	P	4	3	K	1	1	0.166667
3	P	4	3	K	23	5	0.833333
3	P	6	4	K	1	1	0.166667
3	P	6	4	K	23	5	0.833333
3	C	1	1	SC	1	4	0.666667
3	C	1	1	SC	23	2	0.333333
3	C	3	2	SC	1	3	0.5
3	C	3	2	SC	23	3	0.5
3	C	4	3	SC	1	0	0
3	C	4	3	SC	23	6	1
3	C	8	4	SC	1	5	0.833333
3	C	8	4	SC	23	1	0.166667
3	P	2	1	SC	1	0	0
3	P	2	1	SC	23	6	1
3	P	5	2	SC	1	6	1
3	P	5	2	SC	23	0	0
3	P	6	3	SC	1	5	0.833333
3	P	6	3	SC	23	1	0.166667
3	P	7	4	SC	1	0	0
3	P	7	4	SC	23	6	1
4	C	1	1	T	1	2	0.333333
4	C	1	1	T	23	4	0.666667
4	C	2	2	T	1	0	0

4	C	2	2	T	23	6	1
4	C	6	3	T	1	1	0.166667
4	C	6	3	T	23	6	1
4	C	7	4	T	1	0	0
4	C	7	4	T	23	6	1
4	P	3	1	T	1	2	0.333333
4	P	3	1	T	23	4	0.666667
4	P	4	2	T	1	1	0.166667
4	P	4	2	T	23	5	0.833333
4	P	5	3	T	1	0	0
4	P	5	3	T	23	6	1
4	P	8	4	T	1	3	0.5
4	P	8	4	T	23	3	0.5
4	C	2	1	K	1	2	0.333333
4	C	2	1	K	23	4	0.666667
4	C	5	2	K	1	0	0
4	C	5	2	K	23	6	1
4	C	7	3	K	1	2	0.333333
4	C	7	3	K	23	4	0.666667
4	C	8	4	K	1	0	0
4	C	8	4	K	23	6	1
4	P	1	1	K	1	2	0.333333
4	P	1	1	K	23	4	0.666667
4	P	3	2	K	1	0	0
4	P	3	2	K	23	6	1
4	P	4	3	K	1	2	0.333333
4	P	4	3	K	23	4	0.666667
4	P	6	4	K	1	4	0.666667
4	P	6	4	K	23	2	0.333333
4	C	1	1	SC	1	3	0.5
4	C	1	1	SC	23	3	0.5
4	C	3	2	SC	1	3	0.5
4	C	3	2	SC	23	3	0.5
4	C	4	3	SC	1	0	0
4	C	4	3	SC	23	6	1
4	C	8	4	SC	1	0	0
4	C	8	4	SC	23	6	1
4	P	2	1	SC	1	2	0.333333
4	P	2	1	SC	23	4	0.666667
4	P	5	2	SC	1	3	0.5
4	P	5	2	SC	23	3	0.5
4	P	6	3	SC	1	4	0.666667
4	P	6	3	SC	23	2	0.333333
4	P	7	4	SC	1	2	0.333333
4	P	7	4	SC	23	4	0.666667
5	C	1	1	T	1	0	0
5	C	1	1	T	23	6	1
5	C	2	2	T	1	0	0
5	C	2	2	T	23	6	1
5	C	6	3	T	1	0	0

5	C	6	3	T	23	6	1
5	C	7	4	T	1	0	0
5	C	7	4	T	23	6	1
5	P	3	1	T	1	2	0.333333
5	P	3	1	T	23	4	0.666667
5	P	4	2	T	1	2	0.333333
5	P	4	2	T	23	4	0.666667
5	P	5	3	T	1	3	0.5
5	P	5	3	T	23	3	0.5
5	P	8	4	T	1	2	0.333333
5	P	8	4	T	23	4	0.666667
5	C	2	1	K	1	3	0.5
5	C	2	1	K	23	3	0.5
5	C	5	2	K	1	3	0.5
5	C	5	2	K	23	3	0.5
5	C	7	3	K	1	0	0
5	C	7	3	K	23	6	1
5	C	8	4	K	1	1	0.166667
5	C	8	4	K	23	5	0.833333
5	P	1	1	K	1	2	0.333333
5	P	1	1	K	23	4	0.666667
5	P	3	2	K	1	3	0.5
5	P	3	2	K	23	3	0.5
5	P	4	3	K	1	1	0.166667
5	P	4	3	K	23	5	0.833333
5	P	6	4	K	1	3	0.5
5	P	6	4	K	23	3	0.5
5	C	1	1	SC	1	4	0.666667
5	C	1	1	SC	23	0	0
5	C	3	2	SC	1	1	0.166667
5	C	3	2	SC	23	2	0.333333
5	C	4	3	SC	1	0	0
5	C	4	3	SC	23	6	1
5	C	8	4	SC	1	0	0
5	C	8	4	SC	23	6	1
5	P	2	1	SC	1	0	0
5	P	2	1	SC	23	3	0.5
5	P	5	2	SC	1	1	0.166667
5	P	5	2	SC	23	2	0.333333
5	P	6	3	SC	1	2	0.333333
5	P	6	3	SC	23	4	0.666667
5	P	7	4	SC	1	1	0.166667
5	P	7	4	SC	23	3	0.5
6	C	1	1	T	1	0	0
6	C	1	1	T	23	6	1
6	C	2	2	T	1	0	0
6	C	2	2	T	23	6	1
6	C	6	3	T	1	0	0
6	C	6	3	T	23	6	1
6	C	7	4	T	1	1	0.166667

6	C	7	4	T	23	5	0.833333
6	P	3	1	T	1	2	0.333333
6	P	3	1	T	23	4	0.666667
6	P	4	2	T	1	3	0.5
6	P	4	2	T	23	3	0.5
6	P	5	3	T	1	2	0.333333
6	P	5	3	T	23	4	0.666667
6	P	8	4	T	1	1	0.166667
6	P	8	4	T	23	5	0.833333
6	C	2	1	K	1	0	0
6	C	2	1	K	23	6	1
6	C	5	2	K	1	2	0.333333
6	C	5	2	K	23	4	0.666667
6	C	7	3	K	1	0	0
6	C	7	3	K	23	6	1
6	C	8	4	K	1	0	0
6	C	8	4	K	23	6	1
6	P	1	1	K	1	2	0.333333
6	P	1	1	K	23	4	0.666667
6	P	3	2	K	1	0	0
6	P	3	2	K	23	6	1
6	P	4	3	K	1	4	0.666667
6	P	4	3	K	23	2	0.333333
6	P	6	4	K	1	2	0.333333
6	P	6	4	K	23	4	0.666667
6	C	1	1	SC	1	3	0.5
6	C	1	1	SC	23	3	0.5
6	C	3	2	SC	1	2	0.333333
6	C	3	2	SC	23	4	0.666667
6	C	4	3	SC	1	1	0.166667
6	C	4	3	SC	23	5	0.833333
6	C	8	4	SC	1	2	0.333333
6	C	8	4	SC	23	4	0.666667
6	P	2	1	SC	1	2	0.333333
6	P	2	1	SC	23	2	0.333333
6	P	5	2	SC	1	4	0.666667
6	P	5	2	SC	23	0	0
6	P	6	3	SC	1	2	0.333333
6	P	6	3	SC	23	4	0.666667
6	P	7	4	SC	1	1	0.166667
6	P	7	4	SC	23	3	0.5
7	C	1	1	T	1	0	0
7	C	1	1	T	23	6	1
7	C	2	2	T	1	0	0
7	C	2	2	T	23	6	1
7	C	6	3	T	1	0	0
7	C	6	3	T	23	6	1
7	C	7	4	T	1	0	0
7	C	7	4	T	23	6	1
7	P	3	1	T	1	1	0.166667

7	P	3	1	T	23	5	0.833333
7	P	4	2	T	1	0	0
7	P	4	2	T	23	5	0.833333
7	P	5	3	T	1	2	0.333333
7	P	5	3	T	23	4	0.666667
7	P	8	4	T	1	4	0.666667
7	P	8	4	T	23	2	0.333333
7	C	2	1	K	1	3	0.5
7	C	2	1	K	23	3	0.5
7	C	5	2	K	1	1	0.166667
7	C	5	2	K	23	2	0.333333
7	C	7	3	K	1	3	0.5
7	C	7	3	K	23	3	0.5
7	C	8	4	K	1	0	0
7	C	8	4	K	23	6	1
7	P	1	1	K	1	0	0
7	P	1	1	K	23	6	1
7	P	3	2	K	1	3	0.5
7	P	3	2	K	23	3	0.5
7	P	4	3	K	1	0	0
7	P	4	3	K	23	6	1
7	P	6	4	K	1	2	0.333333
7	P	6	4	K	23	4	0.666667
7	C	1	1	SC	1	4	0.666667
7	C	1	1	SC	23	2	0.333333
7	C	3	2	SC	1	2	0.333333
7	C	3	2	SC	23	4	0.666667
7	C	4	3	SC	1	3	0.5
7	C	4	3	SC	23	3	0.5
7	C	8	4	SC	1	3	0.5
7	C	8	4	SC	23	3	0.5
7	P	2	1	SC	1	2	0.333333
7	P	2	1	SC	23	2	0.333333
7	P	5	2	SC	1	2	0.333333
7	P	5	2	SC	23	4	0.666667
7	P	6	3	SC	1	3	0.5
7	P	6	3	SC	23	3	0.5
7	P	7	4	SC	1	4	0.666667
7	P	7	4	SC	23	2	0.333333
8	C	1	1	T	1	0	0
8	C	1	1	T	23	0	0
8	C	2	2	T	1	0	0
8	C	2	2	T	23	0	0
8	C	6	3	T	1	0	0
8	C	6	3	T	23	0	0
8	C	7	4	T	1	0	0
8	C	7	4	T	23	0	0
8	P	3	1	T	1	0	0
8	P	3	1	T	23	0	0
8	P	4	2	T	1	0	0

8	P	4	2	T	23	0	0
8	P	5	3	T	1	0	0
8	P	5	3	T	23	0	0
8	P	8	4	T	1	0	0
8	P	8	4	T	23	0	0
8	C	2	1	K	1	0	0
8	C	2	1	K	23	6	1
8	C	5	2	K	1	2	0.333333
8	C	5	2	K	23	4	0.666667
8	C	7	3	K	1	0	0
8	C	7	3	K	23	6	1
8	C	8	4	K	1	0	0
8	C	8	4	K	23	6	1
8	P	1	1	K	1	2	0.333333
8	P	1	1	K	23	4	0.666667
8	P	3	2	K	1	1	0.166667
8	P	3	2	K	23	5	0.833333
8	P	4	3	K	1	2	0.333333
8	P	4	3	K	23	4	0.666667
8	P	6	4	K	1	0	0
8	P	6	4	K	23	6	1
8	C	1	1	SC	1	2	0.333333
8	C	1	1	SC	23	4	0.666667
8	C	3	2	SC	1	3	0.5
8	C	3	2	SC	23	3	0.5
8	C	4	3	SC	1	0	0
8	C	4	3	SC	23	6	1
8	C	8	4	SC	1	1	0.166667
8	C	8	4	SC	23	5	0.833333
8	P	2	1	SC	1	1	0.166667
8	P	2	1	SC	23	5	0.833333
8	P	5	2	SC	1	2	0.333333
8	P	5	2	SC	23	4	0.666667
8	P	6	3	SC	1	2	0.333333
8	P	6	3	SC	23	1	0.166667
8	P	7	4	SC	1	2	0.333333
8	P	7	4	SC	23	4	0.666667
9	C	1	1	T	1	0	0
9	C	1	1	T	23	0	0
9	C	2	2	T	1	0	0
9	C	2	2	T	23	0	0
9	C	6	3	T	1	0	0
9	C	6	3	T	23	0	0
9	C	7	4	T	1	0	0
9	C	7	4	T	23	0	0
9	P	3	1	T	1	0	0
9	P	3	1	T	23	0	0
9	P	4	2	T	1	0	0
9	P	4	2	T	23	0	0
9	P	5	3	T	1	0	0

9	P	5	3	T	23	0	0
9	P	8	4	T	1	0	0
9	P	8	4	T	23	0	0
9	C	2	1	K	1	0	0
9	C	2	1	K	23	6	1
9	C	5	2	K	1	0	0
9	C	5	2	K	23	6	1
9	C	7	3	K	1	0	0
9	C	7	3	K	23	6	1
9	C	8	4	K	1	0	0
9	C	8	4	K	23	6	1
9	P	1	1	K	1	0	0
9	P	1	1	K	23	6	1
9	P	3	2	K	1	3	0.5
9	P	3	2	K	23	3	0.5
9	P	4	3	K	1	2	0.333333
9	P	4	3	K	23	4	0.666667
9	P	6	4	K	1	2	0.333333
9	P	6	4	K	23	4	0.666667
9	C	1	1	SC	1	0	0
9	C	1	1	SC	23	6	1
9	C	3	2	SC	1	1	0.166667
9	C	3	2	SC	23	5	0.833333
9	C	4	3	SC	1	4	0.666667
9	C	4	3	SC	23	2	0.333333
9	C	8	4	SC	1	3	0.5
9	C	8	4	SC	23	0	0
9	P	2	1	SC	1	4	0.666667
9	P	2	1	SC	23	2	0.333333
9	P	5	2	SC	1	2	0.333333
9	P	5	2	SC	23	4	0.666667
9	P	6	3	SC	1	3	0.5
9	P	6	3	SC	23	1	0.166667
9	P	7	4	SC	1	2	0.333333
9	P	7	4	SC	23	4	0.666667

Appendix: X . Weekly Observations for plant height in cm

Species	Plot	Trt	Rep	Week	HG
Tom	1	C	1	**(2-1)**	4.6
Tom	1	C	1	**(3-2)**	3.2
Tom	1	C	1	**(4-3)**	1.9
Tom	1	C	1	**(5-4)**	3.2
Tom	1	C	1	**(6-5)**	1.9
Tom	1	C	1	**(7-6)**	1
Tom	1	C	1	**(8-7)**	0
Tom	1	C	1	**(9-8)**	0
Tom	2	C	2	**(2-1)**	2
Tom	2	C	2	**(3-2)**	2.4
Tom	2	C	2	**(4-3)**	1.9
Tom	2	C	2	**(5-4)**	4.1
Tom	2	C	2	**(6-5)**	1.9
Tom	2	C	2	**(7-6)**	0.8
Tom	2	C	2	**(8-7)**	0
Tom	2	C	2	**(9-8)**	0
Tom	6	C	3	**(2-1)**	3
Tom	6	C	3	**(3-2)**	1.7
Tom	6	C	3	**(4-3)**	2.3
Tom	6	C	3	**(5-4)**	3.2
Tom	6	C	3	**(6-5)**	2.4
Tom	6	C	3	**(7-6)**	2.3
Tom	6	C	3	**(8-7)**	0
Tom	6	C	3	**(9-8)**	0
Tom	7	C	4	**(2-1)**	5.8
Tom	7	C	4	**(3-2)**	1
Tom	7	C	4	**(4-3)**	1.5
Tom	7	C	4	**(5-4)**	2.8
Tom	7	C	4	**(6-5)**	2.2
Tom	7	C	4	**(7-6)**	1.4
Tom	7	C	4	**(8-7)**	0
Tom	7	C	4	**(9-8)**	0
Tom	3	P	1	**(2-1)**	2.4
Tom	3	P	1	**(3-2)**	1.8
Tom	3	P	1	**(4-3)**	2.8
Tom	3	P	1	**(5-4)**	3
Tom	3	P	1	**(6-5)**	3.2
Tom	3	P	1	**(7-6)**	0.9

Tom	3	P	1	**(8-7)**	0
Tom	3	P	1	**(9-8)**	0
Tom	4	P	2	**(2-1)**	2.1
Tom	4	P	2	**(3-2)**	3.6
Tom	4	P	2	**(4-3)**	3.4
Tom	4	P	2	**(5-4)**	4.1
Tom	4	P	2	**(6-5)**	1.8
Tom	4	P	2	**(7-6)**	1.9
Tom	4	P	2	**(8-7)**	0
Tom	4	P	2	**(9-8)**	0
Tom	5	P	3	**(2-1)**	5.8
Tom	5	P	3	**(3-2)**	1.4
Tom	5	P	3	**(4-3)**	4.1
Tom	5	P	3	**(5-4)**	4.4
Tom	5	P	3	**(6-5)**	1.8
Tom	5	P	3	**(7-6)**	0.6
Tom	5	P	3	**(8-7)**	0
Tom	5	P	3	**(9-8)**	0
Tom	8	P	4	**(2-1)**	5.05
Tom	8	P	4	**(3-2)**	0.6
Tom	8	P	4	**(4-3)**	5.3
Tom	8	P	4	**(5-4)**	3.8
Tom	8	P	4	**(6-5)**	2
Tom	8	P	4	**(7-6)**	0.8
Tom	8	P	4	**(8-7)**	0
Tom	8	P	4	**(9-8)**	0
Collard Green	2	C	1	**(2-1)**	1.8
Collard Green	2	C	1	**(3-2)**	2
Collard Green	2	C	1	**(4-3)**	2.4
Collard Green	2	C	1	**(5-4)**	2.2
Collard Green	2	C	1	**(6-5)**	2.2
Collard Green	2	C	1	**(7-6)**	2
Collard Green	2	C	1	**(8-7)**	2
Collard Green	2	C	1	**(9-8)**	1.4
Collard Green	5	C	2	**(2-1)**	1.5
Collard Green	5	C	2	**(3-2)**	2.7
Collard Green	5	C	2	**(4-3)**	3.9
Collard Green	5	C	2	**(5-4)**	3.2
Collard Green	5	C	2	**(6-5)**	2.8
Collard Green	5	C	2	**(7-6)**	2.2
Collard Green	5	C	2	**(8-7)**	1.8

Collard Green	5	C	2	**(9-8)**	1.2
Collard Green	7	C	3	**(2-1)**	1.5
Collard Green	7	C	3	**(3-2)**	1.9
Collard Green	7	C	3	**(4-3)**	2.5
Collard Green	7	C	3	**(5-4)**	2.6
Collard Green	7	C	3	**(6-5)**	3.4
Collard Green	7	C	3	**(7-6)**	1.2
Collard Green	7	C	3	**(8-7)**	1.9
Collard Green	7	C	3	**(9-8)**	0.7
Collard Green	8	C	4	**(2-1)**	2
Collard Green	8	C	4	**(3-2)**	3.1
Collard Green	8	C	4	**(4-3)**	2.6
Collard Green	8	C	4	**(5-4)**	2.5
Collard Green	8	C	4	**(6-5)**	2.3
Collard Green	8	C	4	**(7-6)**	1.2
Collard Green	8	C	4	**(8-7)**	1.3
Collard Green	8	C	4	**(9-8)**	0.3
Collard Green	1	P	1	**(2-1)**	3
Collard Green	1	P	1	**(3-2)**	2
Collard Green	1	P	1	**(4-3)**	2.2
Collard Green	1	P	1	**(5-4)**	1.6
Collard Green	1	P	1	**(6-5)**	3.2
Collard Green	1	P	1	**(7-6)**	1.3
Collard Green	1	P	1	**(8-7)**	1.8
Collard Green	1	P	1	**(9-8)**	0.4
Collard Green	3	P	2	**(2-1)**	2
Collard Green	3	P	2	**(3-2)**	4.5
Collard Green	3	P	2	**(4-3)**	3
Collard Green	3	P	2	**(5-4)**	1.8
Collard Green	3	P	2	**(6-5)**	2.7
Collard Green	3	P	2	**(7-6)**	1.3
Collard Green	3	P	2	**(8-7)**	0.6
Collard Green	3	P	2	**(9-8)**	0.5
Collard Green	4	P	3	**(2-1)**	3
Collard Green	4	P	3	**(3-2)**	3.8
Collard Green	4	P	3	**(4-3)**	2.3
Collard Green	4	P	3	**(5-4)**	2.8
Collard Green	4	P	3	**(6-5)**	4.1
Collard Green	4	P	3	**(7-6)**	1.3
Collard Green	4	P	3	**(8-7)**	0.6
Collard Green	4	P	3	**(9-8)**	0.8

Collard Green	6	P	4	**(2-1)**	3
Collard Green	6	P	4	**(3-2)**	2.1
Collard Green	6	P	4	**(4-3)**	3.9
Collard Green	6	P	4	**(5-4)**	2.5
Collard Green	6	P	4	**(6-5)**	2.4
Collard Green	6	P	4	**(7-6)**	1.5
Collard Green	6	P	4	**(8-7)**	0.9
Collard Green	6	P	4	**(9-8)**	0.8
S. chard	1	C	1	**(2-1)**	1
S. chard	1	C	1	**(3-2)**	4.5
S. chard	1	C	1	**(4-3)**	2.9
S. chard	1	C	1	**(5-4)**	1.2
S. chard	1	C	1	**(6-5)**	1.8
S. chard	1	C	1	**(7-6)**	1.9
S. chard	1	C	1	**(8-7)**	2.7
S. chard	1	C	1	**(9-8)**	0.6
S. chard	3	C	2	**(2-1)**	1
S. chard	3	C	2	**(3-2)**	3.7
S. chard	3	C	2	**(4-3)**	4.1
S. chard	3	C	2	**(5-4)**	2.2
S. chard	3	C	2	**(6-5)**	2.6
S. chard	3	C	2	**(7-6)**	1.1
S. chard	3	C	2	**(8-7)**	1.1
S. chard	3	C	2	**(9-8)**	2.3
S. chard	4	C	3	**(2-1)**	0.8
S. chard	4	C	3	**(3-2)**	3.9
S. chard	4	C	3	**(4-3)**	4
S. chard	4	C	3	**(5-4)**	2.6
S. chard	4	C	3	**(6-5)**	1
S. chard	4	C	3	**(7-6)**	1.7
S. chard	4	C	3	**(8-7)**	1.2
S. chard	4	C	3	**(9-8)**	1.8
S. chard	8	C	4	**(2-1)**	1.2
S. chard	8	C	4	**(3-2)**	2.6
S. chard	8	C	4	**(4-3)**	3.1
S. chard	8	C	4	**(5-4)**	3.8
S. chard	8	C	4	**(6-5)**	3
S. chard	8	C	4	**(7-6)**	2.3
S. chard	8	C	4	**(8-7)**	1.1
S. chard	8	C	4	**(9-8)**	0.9
S. chard	2	P	1	**(2-1)**	1.5

S. chard	2	P	1	**(3-2)**	4.1
S. chard	2	P	1	**(4-3)**	4.7
S. chard	2	P	1	**(5-4)**	1.7
S. chard	2	P	1	**(6-5)**	1.1
S. chard	2	P	1	**(7-6)**	1.2
S. chard	2	P	1	**(8-7)**	1
S. chard	2	P	1	**(9-8)**	2
S. chard	5	P	2	**(2-1)**	1.2
S. chard	5	P	2	**(3-2)**	1.5
S. chard	5	P	2	**(4-3)**	2.8
S. chard	5	P	2	**(5-4)**	3.3
S. chard	5	P	2	**(6-5)**	2
S. chard	5	P	2	**(7-6)**	1.6
S. chard	5	P	2	**(8-7)**	1.6
S. chard	5	P	2	**(9-8)**	0.8
S. chard	6	P	3	**(2-1)**	2
S. chard	6	P	3	**(3-2)**	4.1
S. chard	6	P	3	**(4-3)**	2.1
S. chard	6	P	3	**(5-4)**	2.3
S. chard	6	P	3	**(6-5)**	1.9
S. chard	6	P	3	**(7-6)**	0.9
S. chard	6	P	3	**(8-7)**	0.9
S. chard	6	P	3	**(9-8)**	1.8
S. chard	7	P	4	**(2-1)**	0.8
S. chard	7	P	4	**(3-2)**	3.9
S. chard	7	P	4	**(4-3)**	2.9
S. chard	7	P	4	**(5-4)**	3
S. chard	7	P	4	**(6-5)**	3.1
S. chard	7	P	4	**(7-6)**	1.7
S. chard	7	P	4	**(8-7)**	1.3
S. chard	7	P	4	**(9-8)**	0.8